Powering of Future HEP Detectors in 4T & High Radiation - Commercial solutions?

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Yale University

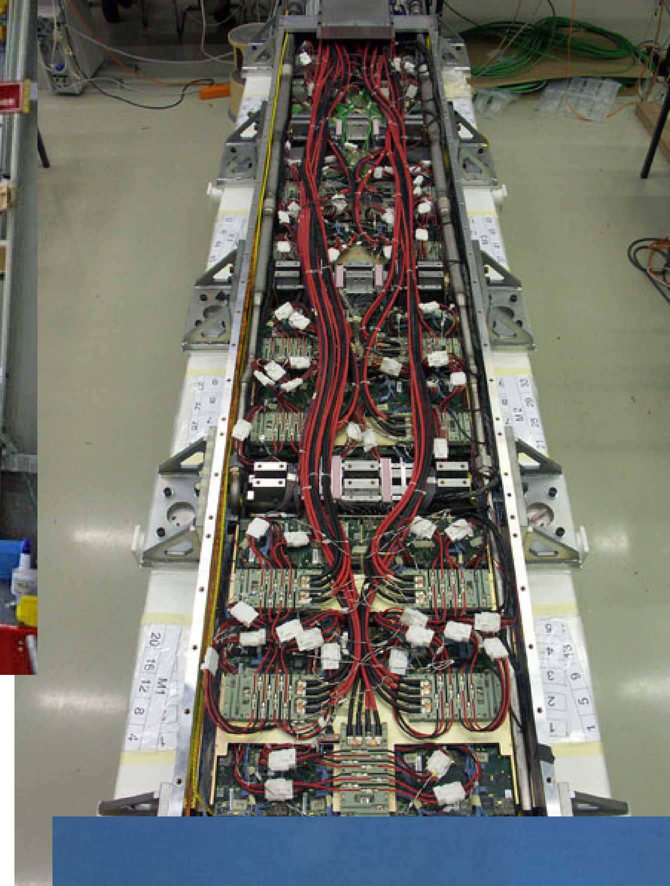
Technical Seminar at TRIUMF
August 5, 2010

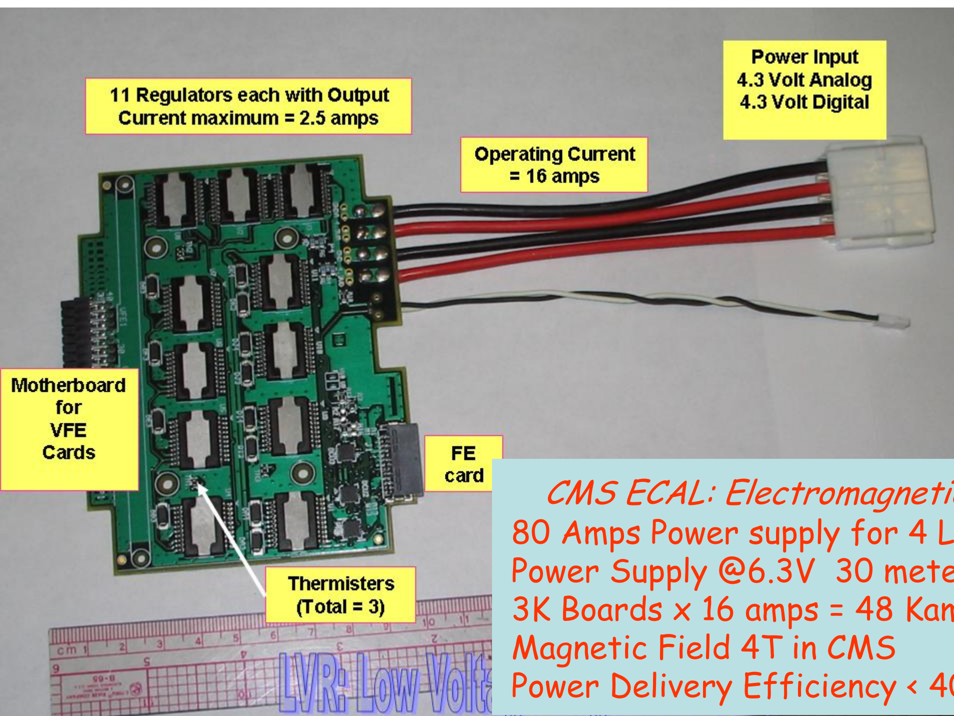
1 Oodle = 10,000 amps

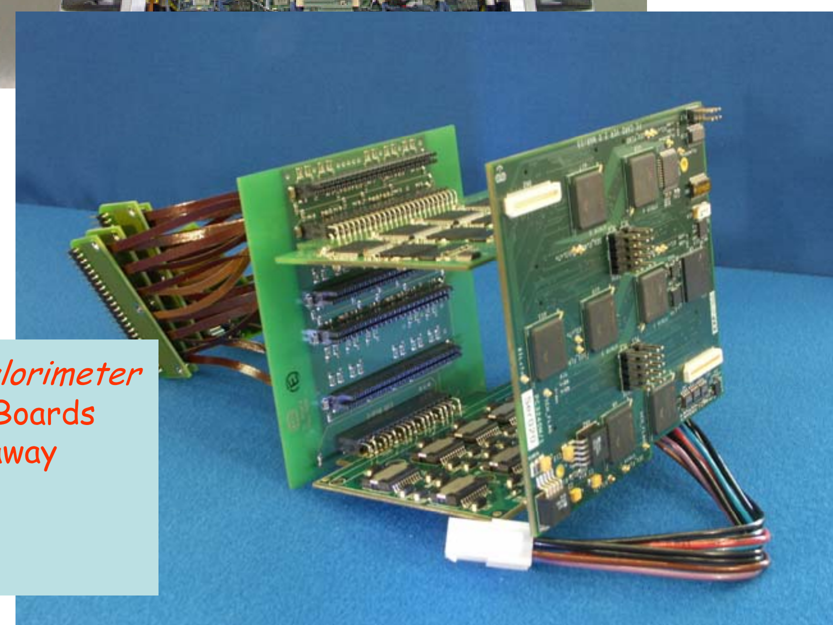
Agenda

- CMS ECAL Powering 2.5 V @ 50,000 amps
- DC-DC Converters: *Reduce Power Supply Currents*
- Commercial Device 100 Mrads- Beginners luck
- ATLAS Upgrade
- Air Coil , Noise tests
- Why Thin Oxide for Radiation
- End of Silicon for Power
- GaN Wide band Gap material. RF & Power Switching
- Industry Developments 400V DC distribution
- Did we find a commercial part for sLHC ?
- Market Trends Single Chip
- LHC Beam Power Supplies
- Advantage of this development
- Conclusions

Collaborators:
Yale University: Keith Baker, Hunter Smith
Brookhaven National Laboratory: Hucheng Chen, James Kierstead, Francesco Lanni, David Lynn, Sergio Rescia,







CMS ECAL: Electromagnetic Calorimeter

80 Amps Power supply for 4 LVR Boards

Power Supply @6.3V 30 meters away

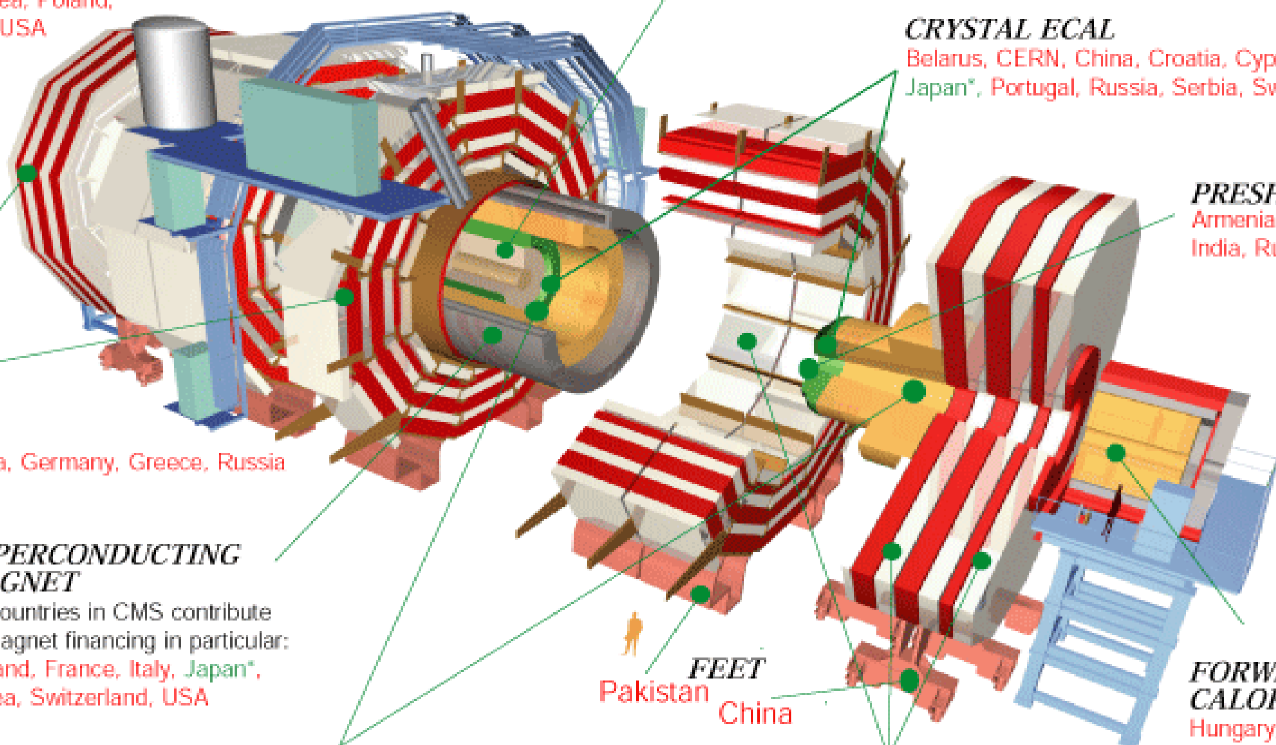
3K Boards x 16 amps = 48 Kamps

Magnetic Field 4T in CMS

Power Delivery Efficiency < 40 %

CMS Outreach

37 Countries, 155 Institutes, 2000 scientists (including about 400 students) October 2006



TRACKER
Austria, Belgium, CERN, Finland, France, Germany, Italy, Japan*, Mexico, New Zealand, Switzerland, UK, USA

TRIGGER, DATA ACQUISITION & OFFLINE COMPUTING
Austria, Brazil, CERN, Finland, France, Greece, Hungary, Ireland, Italy, Korea, Poland, Portugal, Switzerland, UK, USA

CRYSTAL ECAL
Belarus, CERN, China, Croatia, Cyprus, France, Italy, Japan*, Portugal, Russia, Serbia, Switzerland, UK, USA

PRESHOWER
Armenia, CERN, Greece, India, Russia, Taiwan

RETURN YOKE
Barrel: Czech Rep., Estonia, Germany, Greece, Russia
Endcap: Japan*, USA

SUPERCONDUCTING MAGNET
All countries in CMS contribute to Magnet financing in particular: Finland, France, Italy, Japan*, Korea, Switzerland, USA

FEET
Pakistan
China

FORWARD CALORIMETER
Hungary, Iran, Russia, Turkey, USA

HCAL
Barrel: Bulgaria, India, Spain*, USA
Endcap: Belarus, Bulgaria, Georgia, Russia, Ukraine, Uzbekistan
HO: India

MUON CHAMBERS
Barrel: Austria, Bulgaria, CERN, China, Germany, Hungary, Italy, Spain,
Endcap: Belarus, Bulgaria, China, Colombia, Korea, Pakistan, Russia, USA

* Only through industrial contracts

Total weight	:	**12500 T**
Overall diameter	:	**15.0 m**
Overall length	:	**21.5 m**
Magnetic field	:	**4 Tesla**

CMS ECAL: 5 Oodles (50 Kamps) .

Power Supply output	= 315 KW
Power loss in Leads to SM	= 100 KW
Power loss in Regulator Card	= 90 KW
Power Delivered @ 2.5 V	= 125 KW

1 Oodle = 10,000 amps

# of Power Supplies ~ 700
# of ST LDO Chips = 35 K LHC Radiation Hard made by ST Microelectronics
# of LVR Cards = 3.1 K.

Yale: Designed, built, burn-in and Tested.

Power Supply
6.3 V

64 Amps

30 m

Vdrop = 2V
Pd = 128 W

$50\ mm^2$ (AWG 00)

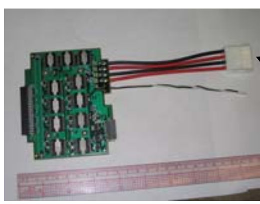
$2 \times 16\ mm^2$ (AWG 6)

1 to 3 m

SM: Super Module

Junction Box

4.3 V

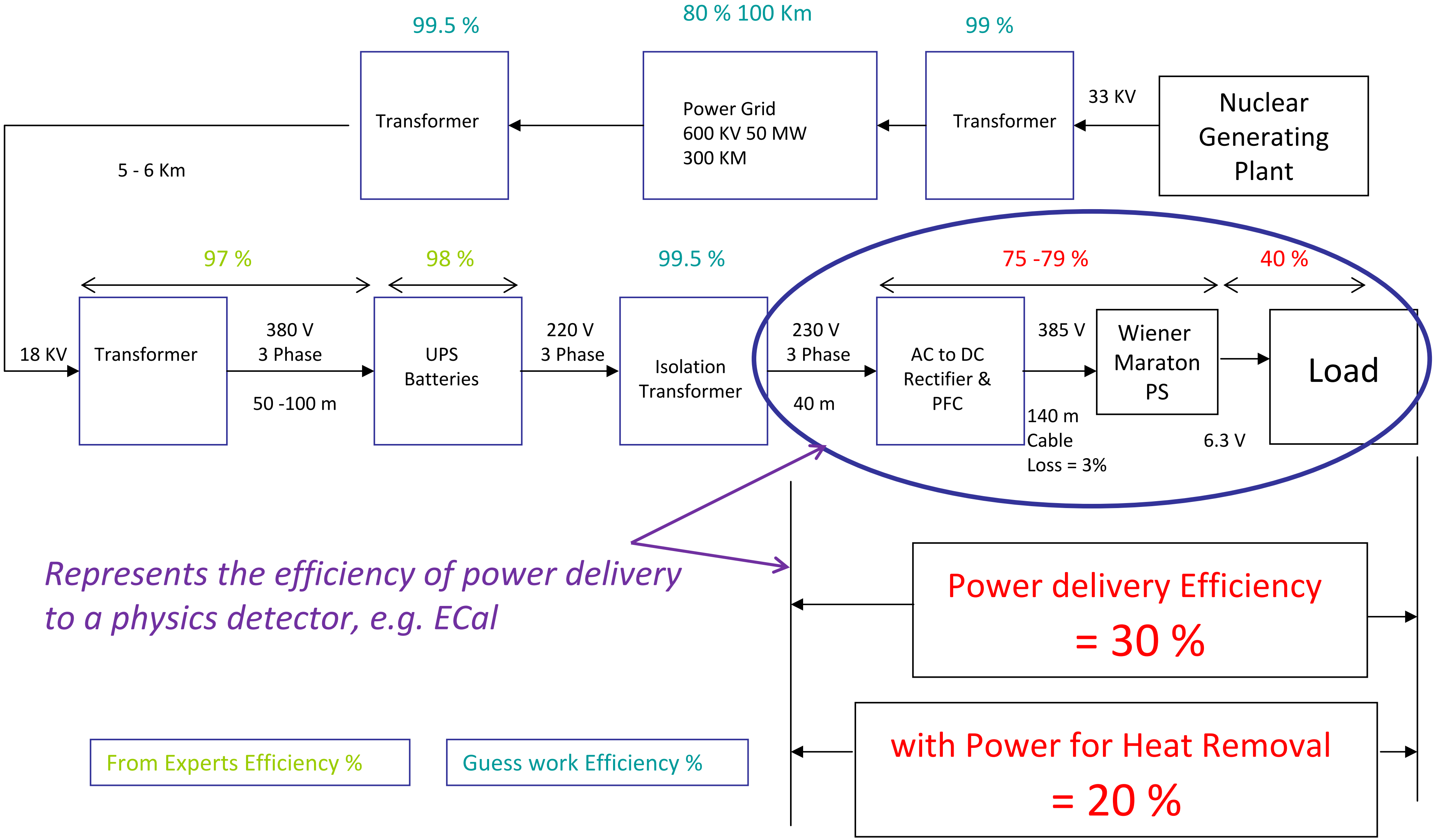


2.5V
64 amps
160 W

4 LVR Boards

Power Delivery Efficiency = 40%
NOT INCLUDED
1. Power Supply efficiency
2. Water cooling
3. Removal of Waste heat
4. Air Conditioning

Power Chain Efficiency for CMS ECAL



What can we do?

- Is there a better way to distribute power ?
- High Radiation
- Magnetic Field 4 T
- Load ~1 V Oodles of current
- Feed High Voltage and Convert - *like AC power transmission*
- Commercial Technologies – *No Custom ASIC Chips*
- Learn from Semiconductor Industry
- Use Company Evaluation Boards for testing

Type of High to Low Voltage Converters without transformers

❖ Charge pumps

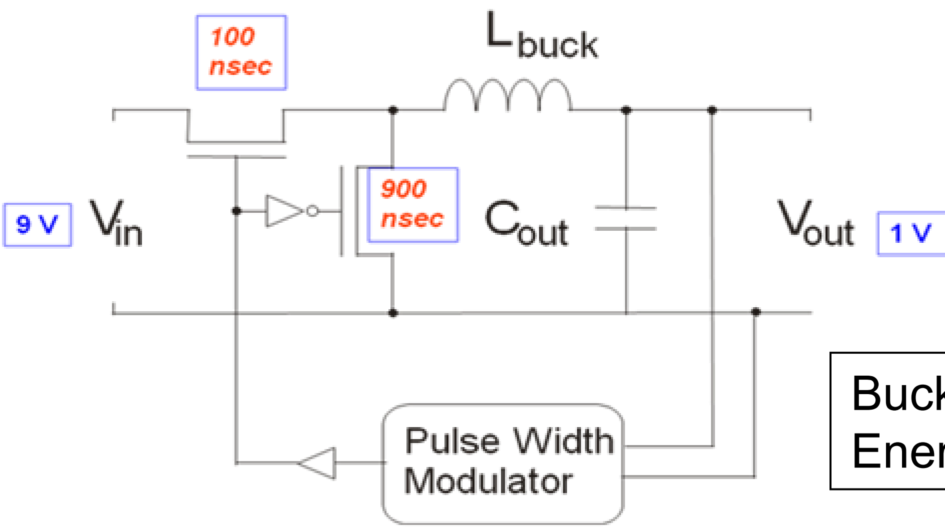
- Normally limited to integral fractions of input voltage
- Losses proportional to switch losses
- Can provide negative voltage

❖ Buck Converter – Used in consumer & Industrial Electronics

- Needs an ASIC, Inductor and Capacitors
- Cannot provide a negative voltage
- Topology allows for more flexibility in output voltage than charge pump
- Much more common use in commercial applications

8

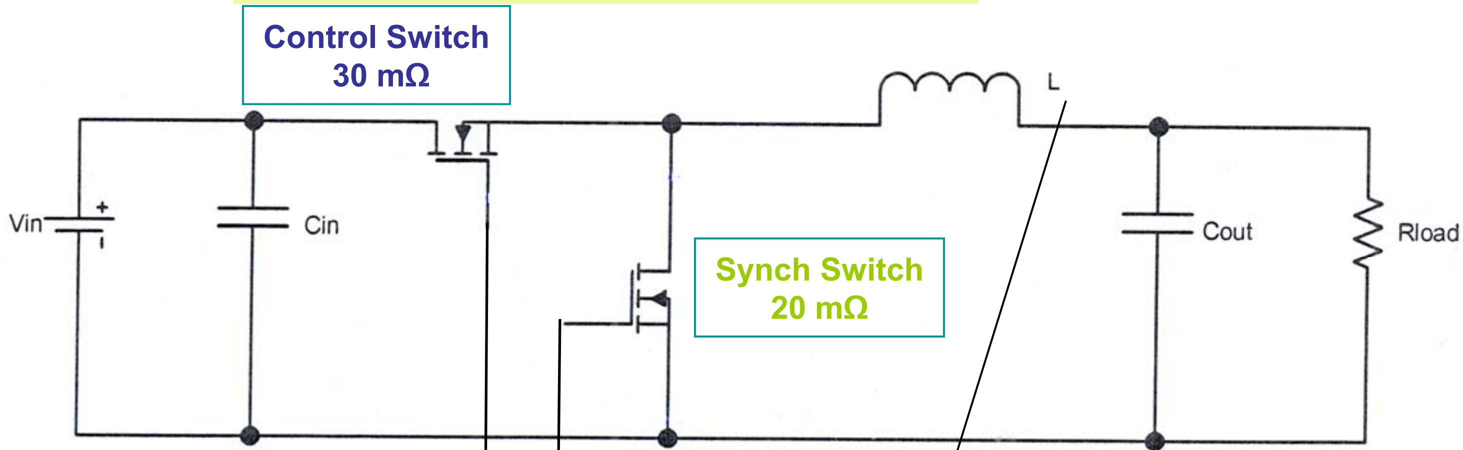
Charge Pump: Charge capacitors in series & discharge in parallel



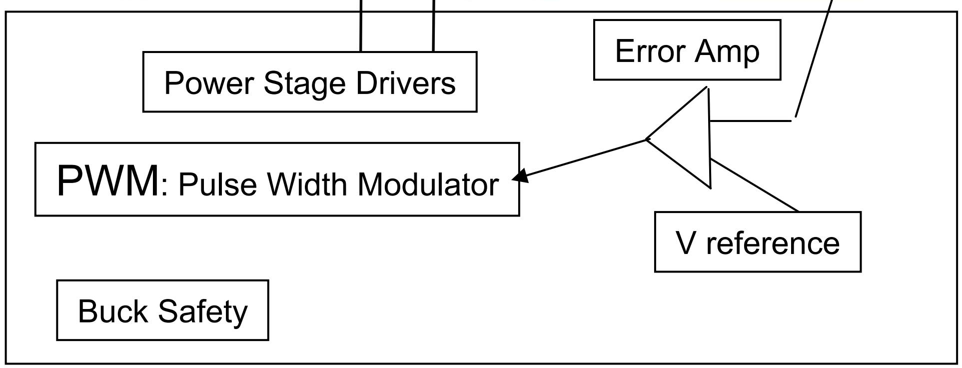
Buck Converter
Energy Stored in an inductor

Synchronous Buck Converter

Power Stage
-
High Volts

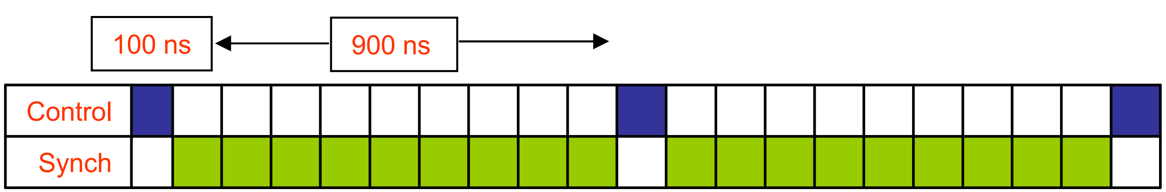


Controller
Low Voltage



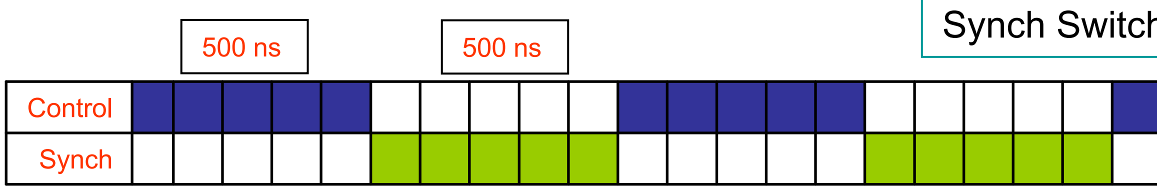
Minimum Switch ON Time
Limits Max Frequency
10 nsec @ 10 MHz

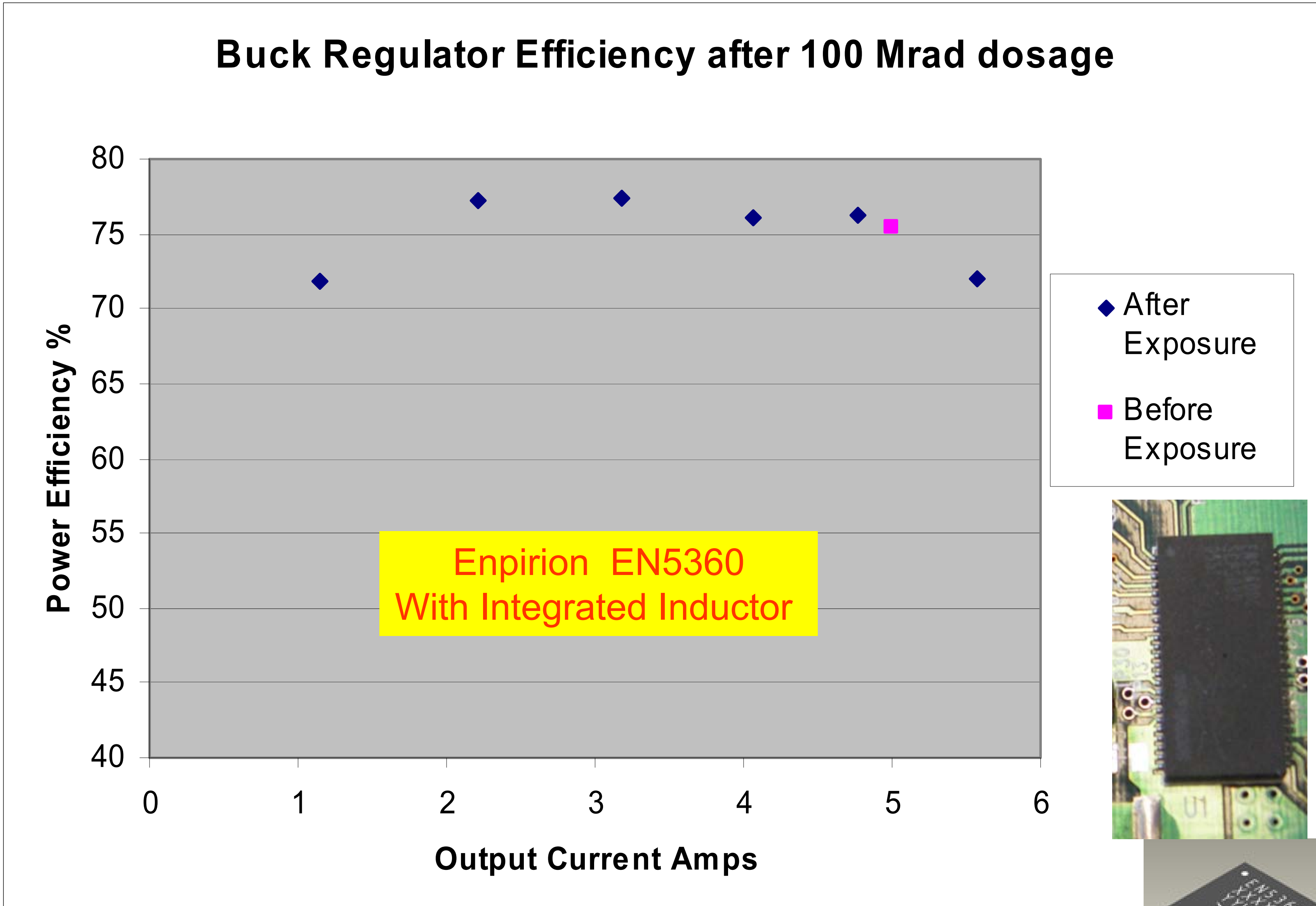
Vout = 11%

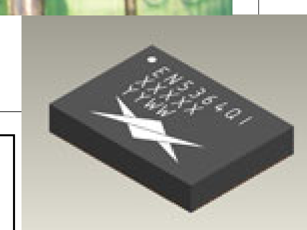


Control Switch: Switching Loss > I^2
Synch Switch: Rds Loss Significant

Vout = 50%

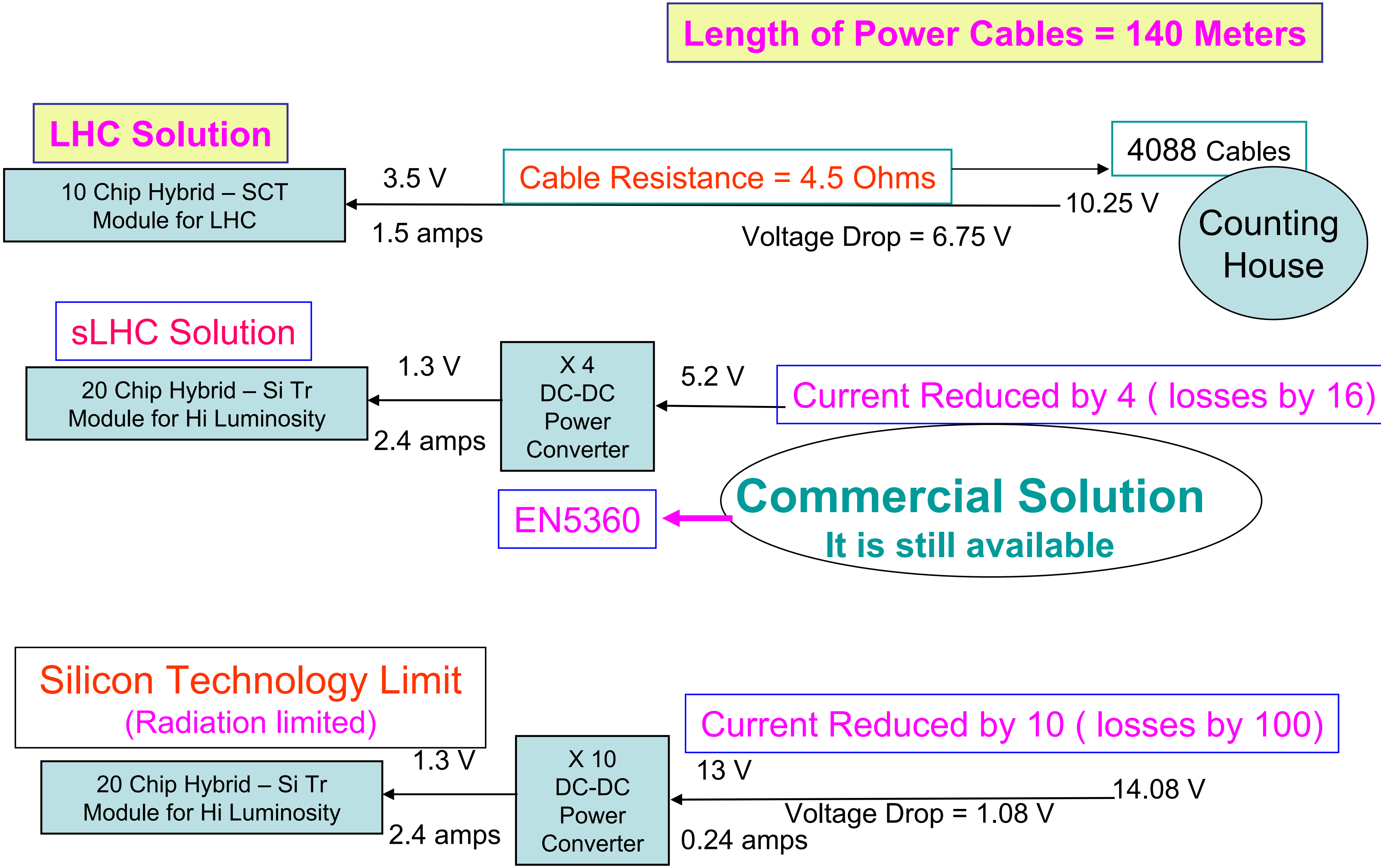




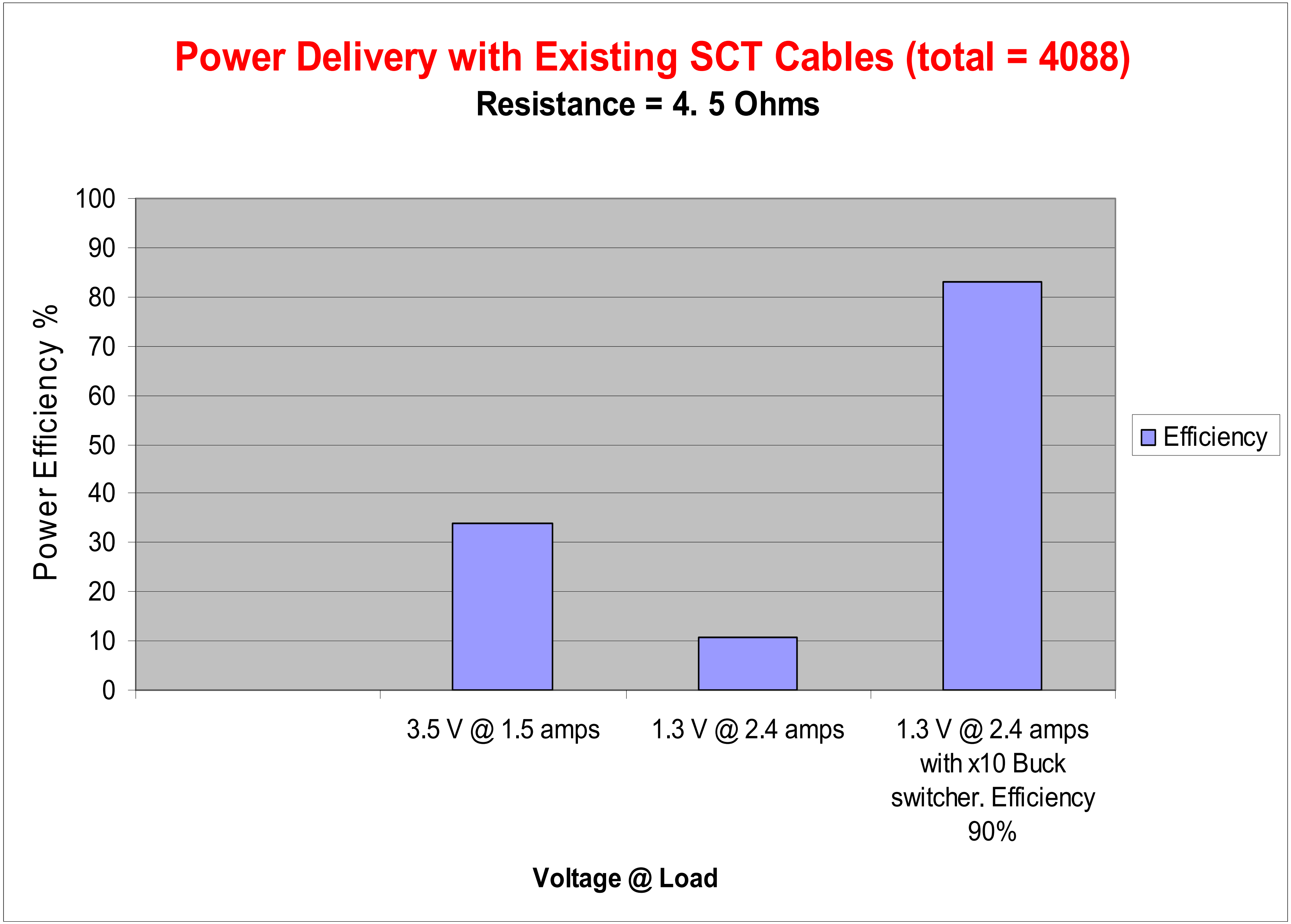


Found out at Power Technology conference 0.25 µm Lithography

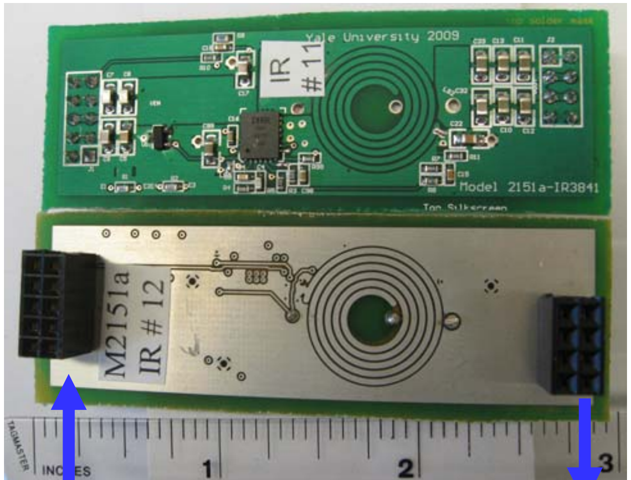
- Irradiated Stopped on St. Valentines Day 2007
- We reported @ TWEPP 2008 - IHP was foundry for EN5360



> X 40 with Gallium Nitride Transistors


Power Delivery with Existing SCT Cables (total = 4088)
Resistance = 4. 5 Ohms
Power Efficiency %
100
90
80
70
60
50
40
30
20
10
0
3.5 V @ 1.5 amps
1.3 V @ 2.4 amps
1.3 V @ 2.4 amps with x10 Buck switcher. Efficiency 90%
Voltage @ Load
Efficiency

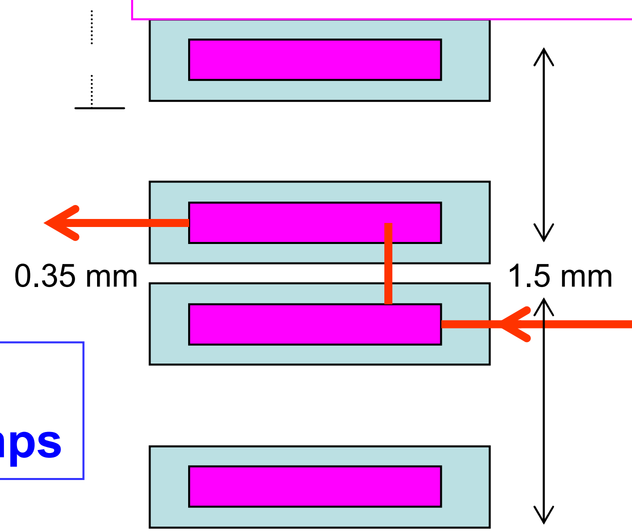
Plug In Card with Shielded Buck Inductor

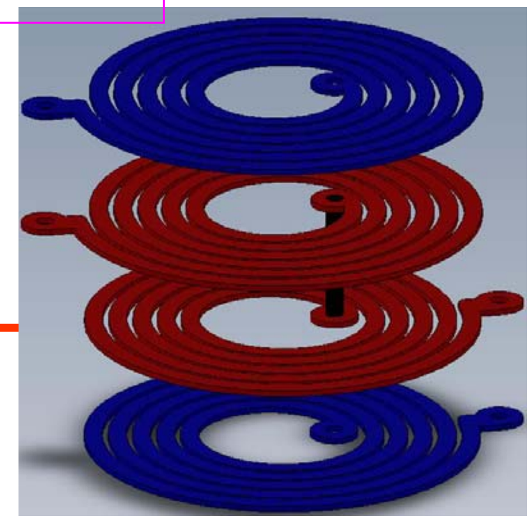


12 V

2.5 V
@ 6 amps

Coupled Air Core Inductor Connected in Series





Spiral Coils Resistance in mΩ

	Top	Bottom
3 Oz PCB	57	46
0.25 mm Cu Foil	19.4	17

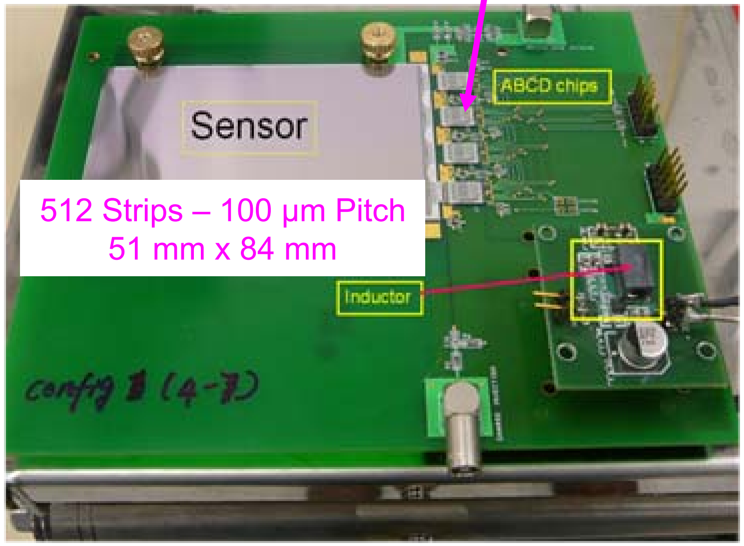
Different Versions

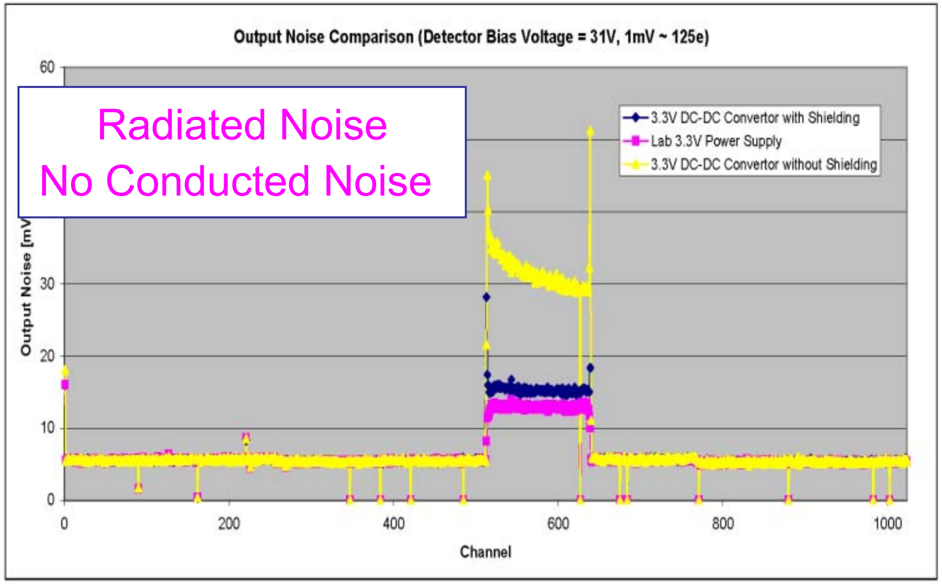
- Converter Chips
  - Max8654 monolithic
  - IR8341 3 die MCM
- Coils
  - Embedded 3oz cu
  - Solenoid 15 mΩ
  - Spiral Etched 0.25mm

Noise Tests with Silicon Sensors

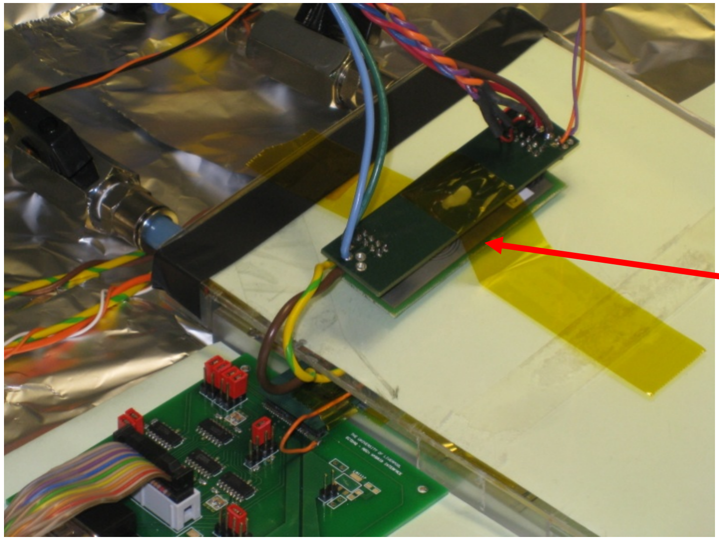
Test @ BNL

Only One Chip Bonded





Test @ Liverpool

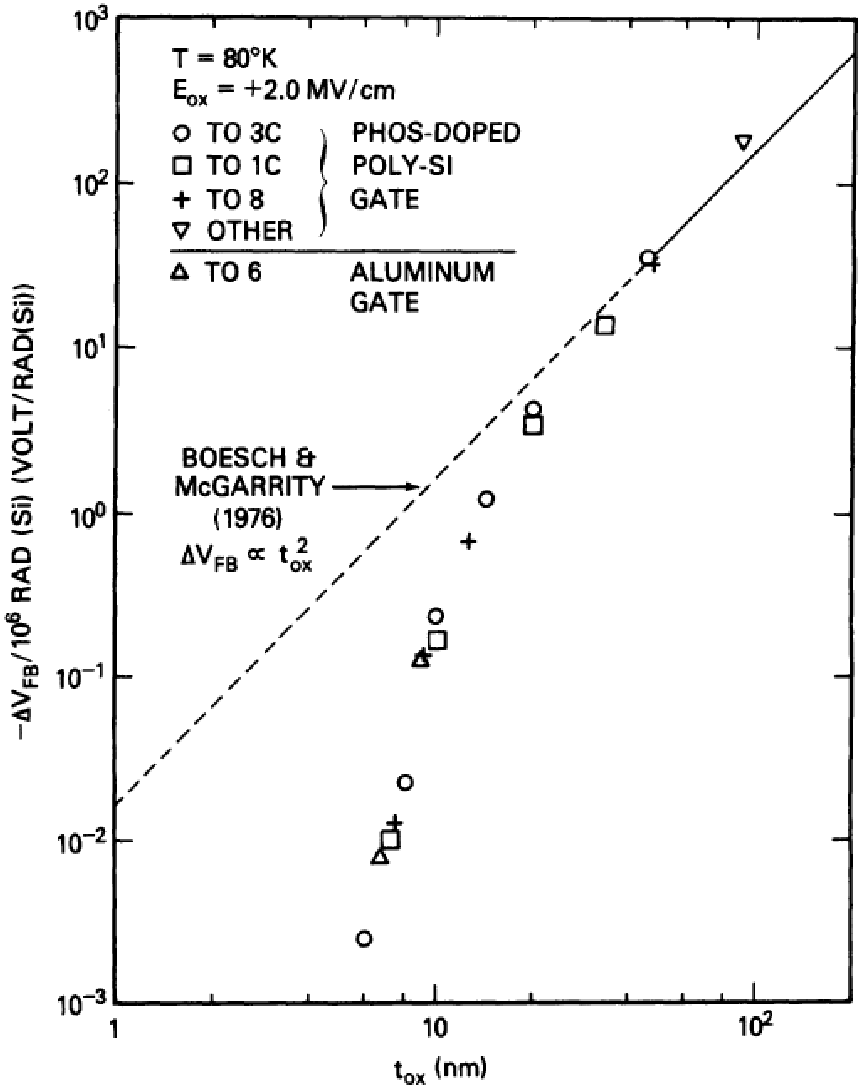


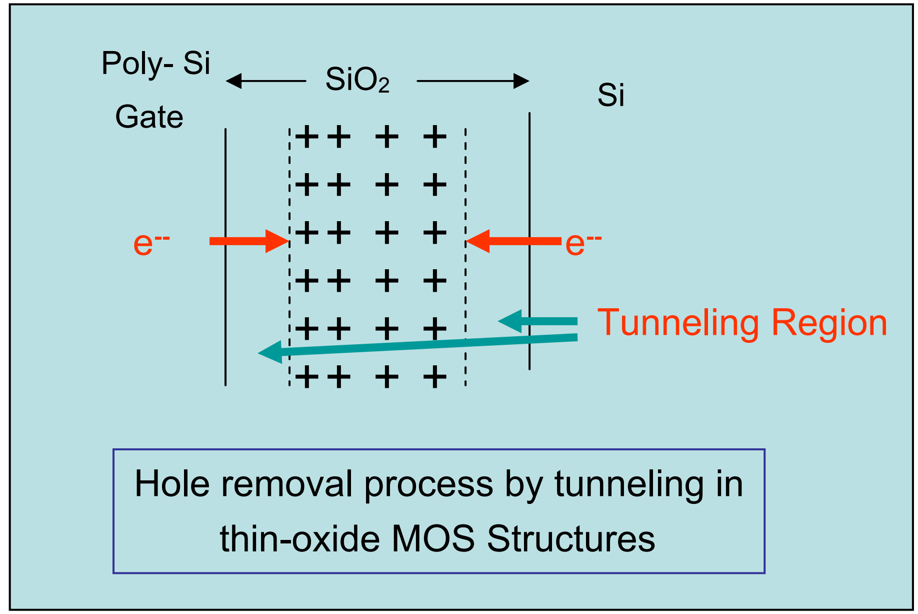
Plug in Card
1 cm from Coil
facing Sensor

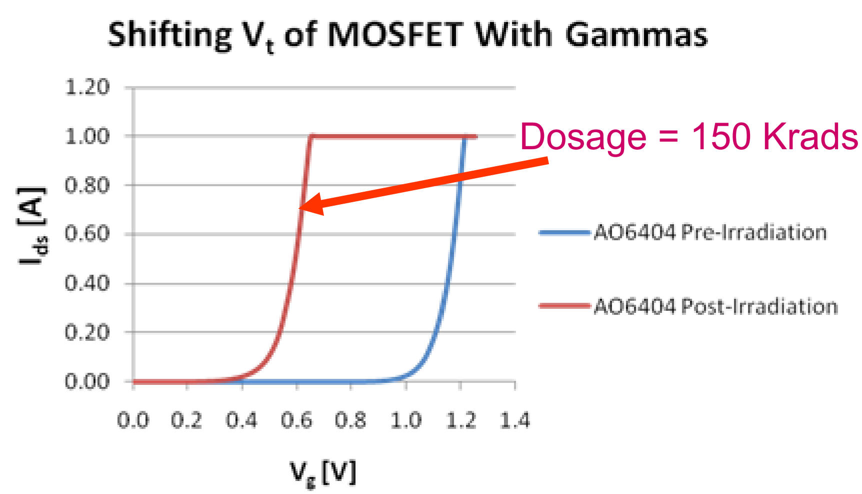
20 µm Al foil
shielding

Coil Type	Power	Input Noise electrons rms
Solenoid	DC - DC	881
Solenoid	Linear	885
Spiral Coil	DC - DC	666
Spiral Coil	Linear	664

Threshold Shift vs Gate Oxide Thickness







Sachs et. al. IEEE Trans. Nuclear Science NS-31, 1249 (1984)

Book. Timothy R Oldham "Ionizing Radiation Effects in MOS Oxides" 1999 World Scientific

CERN ASICs

Mantra: Deep sub micron is more rad hard

Why ?

IBM Foundry Oxide Thickness			
Lithography	Process	Operating	Oxide
	Name	Voltage	Thickness
			nm
0.25 μm	6SF	2.5	5
		3.3	7
0.13 μm	8RF	1.2 & 1.5	2.2
		2.2 & 3.3	5.2

Can We Have
High Radiation Tolerance & Higher Voltage Together ???

Higher radiation tolerance needs thin oxide
while higher voltage needs thicker oxide – Contradiction ?

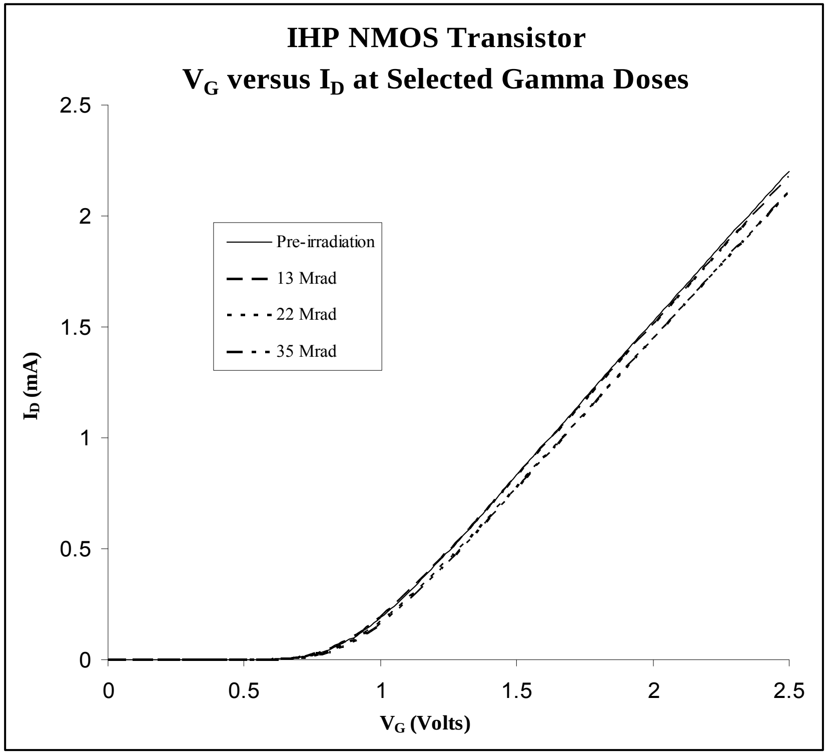
Mixed signal power designs from TI, TSMC, IBM etc - 0.18 μm & 0.13 μm
Automobile Market. Voltage ratings 10 - 80 Volts
Deep sub-micron but thick oxide

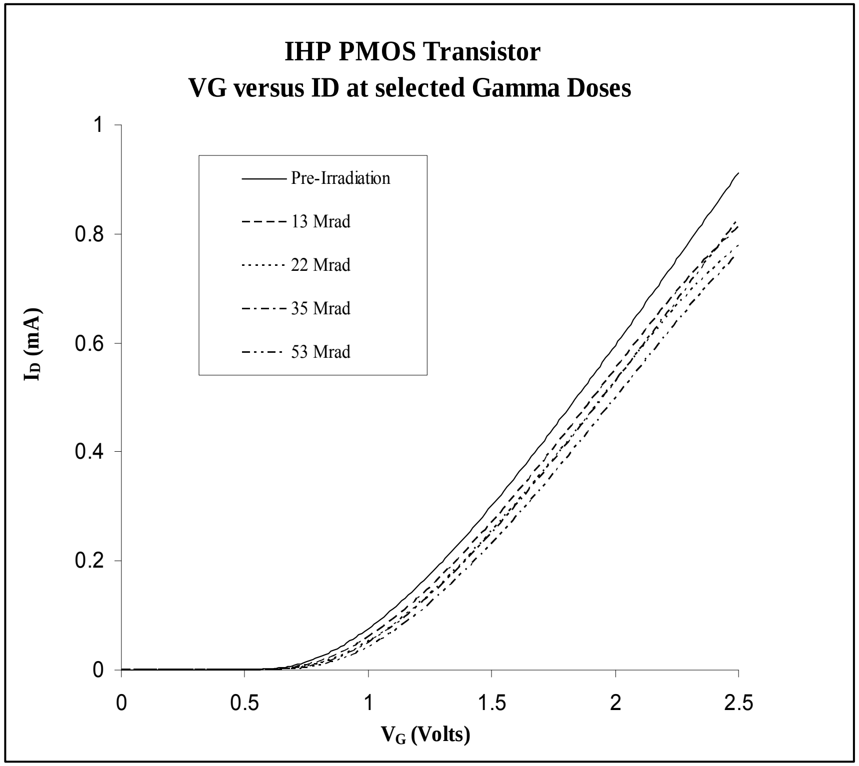
Controller : Low Voltage

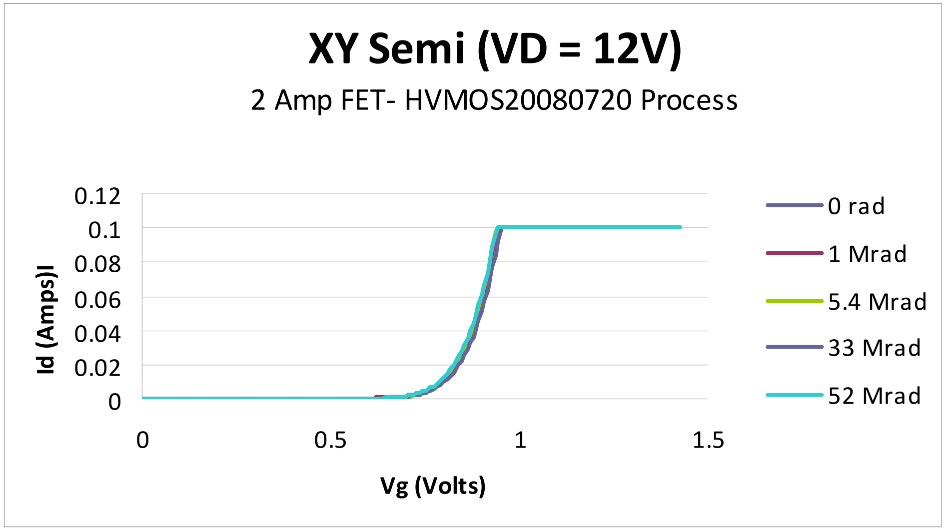
High Voltage: Switches – some candidates HV & Thin oxide

LDMOS, Drain Extension, Deep Diffusion etc

>> 20 Volts HEMT GaN on Silicon, Silicon Carbide, Sapphire


IHP NMOS Transistor
V_G versus I_D at Selected Gamma Doses
I_D (mA)
V_G (Volts)
Pre-irradiation
13 Mrad
22 Mrad
35 Mrad
0
0.5
1
1.5
2
2.5


IHP PMOS Transistor
VG versus ID at selected Gamma Doses
I_D (mA)
V_G (Volts)
Pre-Irradiation
13 Mrad
22 Mrad
35 Mrad
53 Mrad
0
0.2
0.4
0.6
0.8
1
0.5
1.5
2
2.5


XY Semi (VD = 12V)
2 Amp FET- HVMOS20080720 Process
Id (Amps)l
Vg (Volts)
0 rad
1 Mrad
5.4 Mrad
33 Mrad
52 Mrad
0
0.02
0.04
0.06
0.08
0.1
0.12
0.5
1
1.5

Thin Oxide Devices (non IBM)

Company	Device	Process	Foundry	Oxide	Dose before	Observation
		Name/ Number	Name	nm	Damage seen	Damage Mode
IHP	ASIC custom	SG25V GOD **12 V**	IHP, Germany	5		Minimal Damage
XySemi	FET 2 amps	HVMOS20080720 **12 V**	China	7		Minimal Damage
XySemi	XP2201	HVMOS20080720 **15 V**	China	12 / 7		2Q2010
Enpirion	EN5365	CMOS 0.25 µm	Dongbu HiTek, Korea	5	64 Krads	
Enpirion	EN5382	CMOS 0.25 µm	Dongbu HiTek, Korea	5	111 Krads	
Enpirion	EN5360 #2	SG25V (IHP)	IHP, Germany	5	100 Mrads	Minimal Damage
Enpirion	EN5360 #3	SG25V (IHP)	IHP, Germany	5	48 Mrads	Minimal Damage

Necessary condition for Radiation Hardness - Thin Gate Oxide

But not sufficient

IHP: Epi free, High resistivity substrate, Higher voltage, lower noise devices

Dongbu: Epi process on substrate, lower voltage due to hot carriers in gate oxide

Gallium Nitride Devices Tests 2009

RF GaN 20 Volts & 0.1 amp

- ❖ 8 pieces: Nitronex NPT 25015: GaN on Silicon
  - ✓ Done Gamma, Proton & Neutrons
  - ✓ 65 volts Oct 2009

- ❖ 2 pieces: CREE CGH40010F: GaN on siC

- ❖ 6 pieces: Eudyna EGNB010MK: GaN on siC
  - ✓ Done Neutrons

Switch GaN

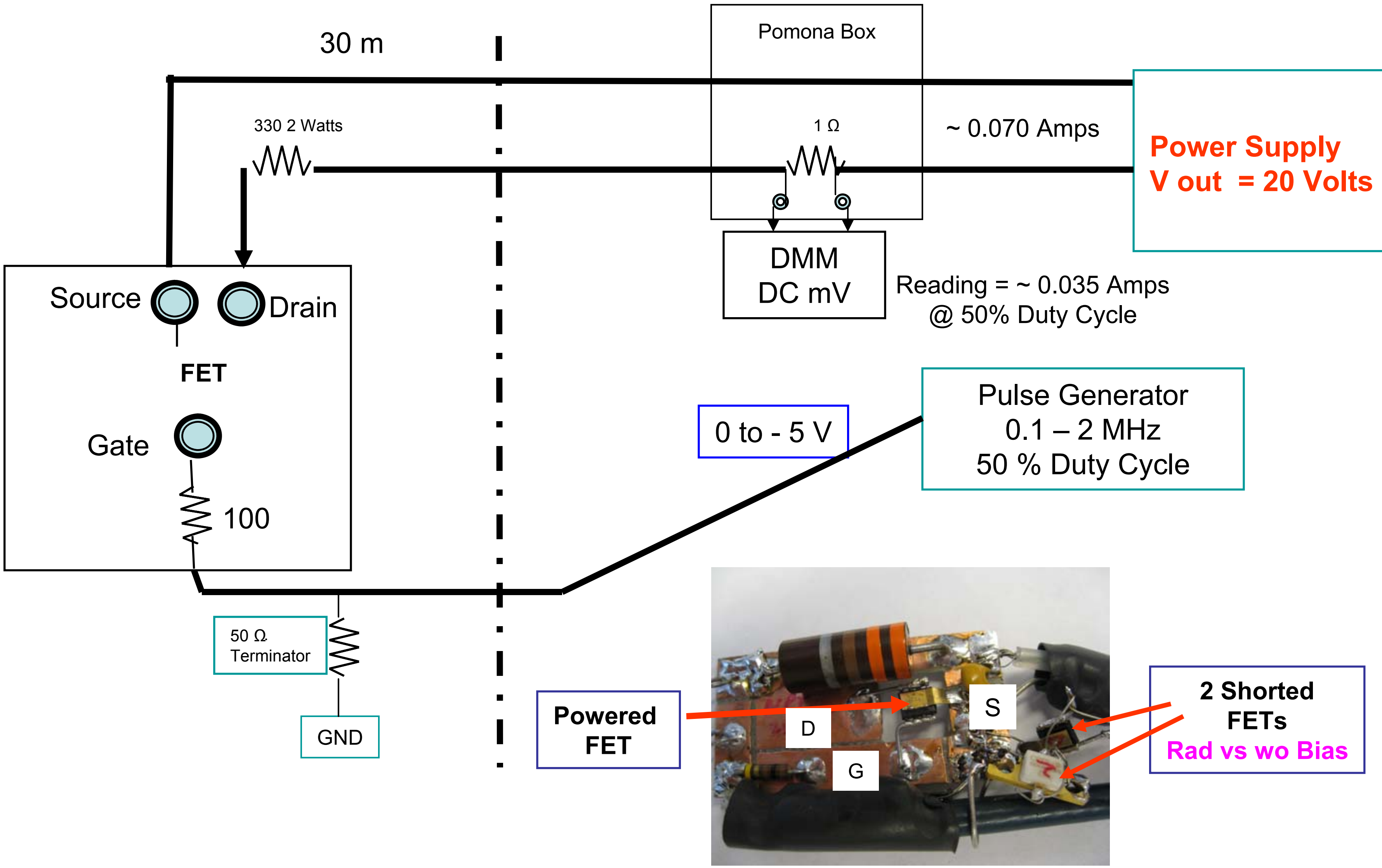
- ❖ International Rectifier GaN on Silicon
  Under NDA

Gamma: @ BNL
Protons: @ Lansce
Neutrons: @ U of Mass Lowell

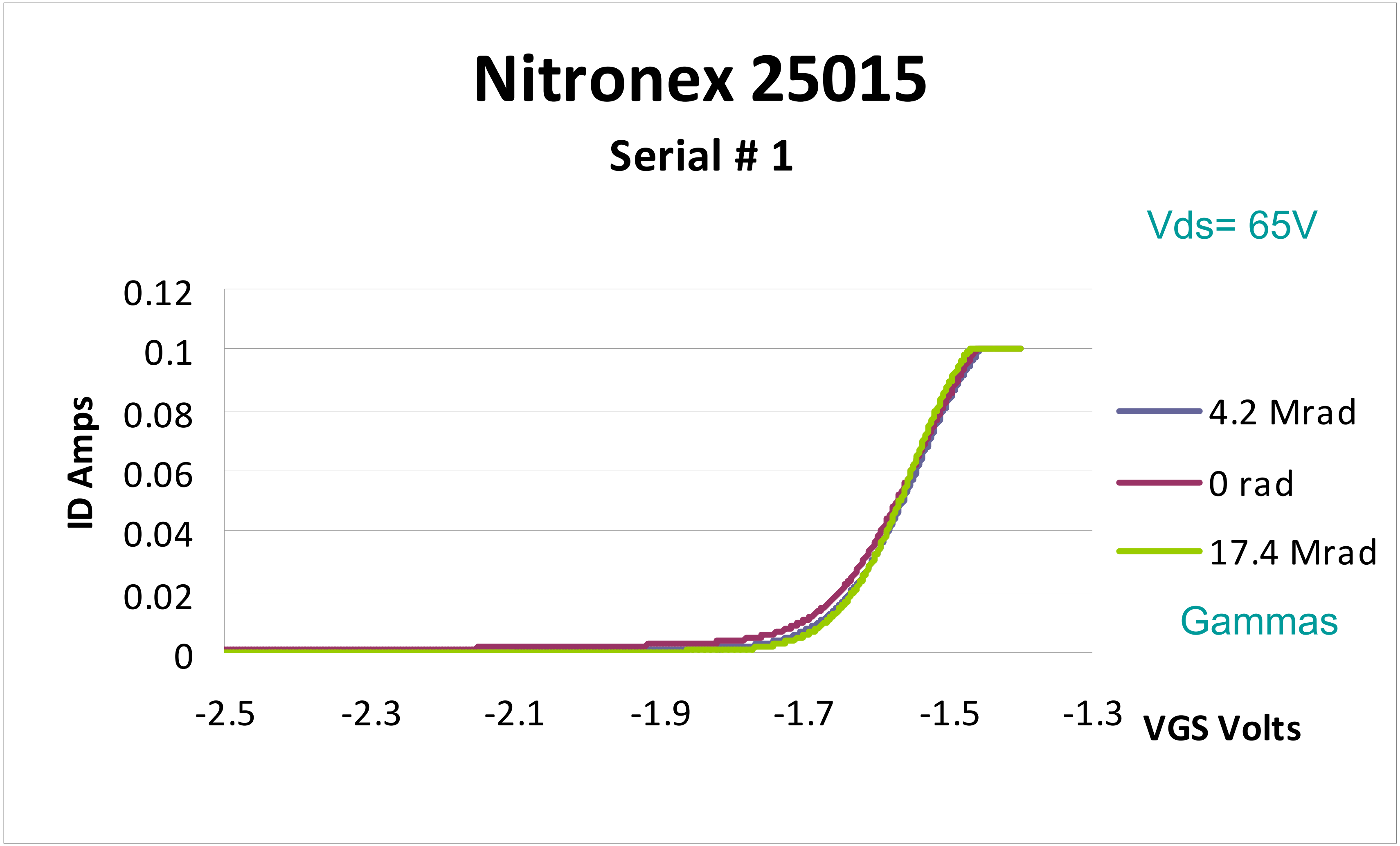
Expose same device to
Gamma, Protons & Neutrons
Online Monitoring

Bias during Radiation

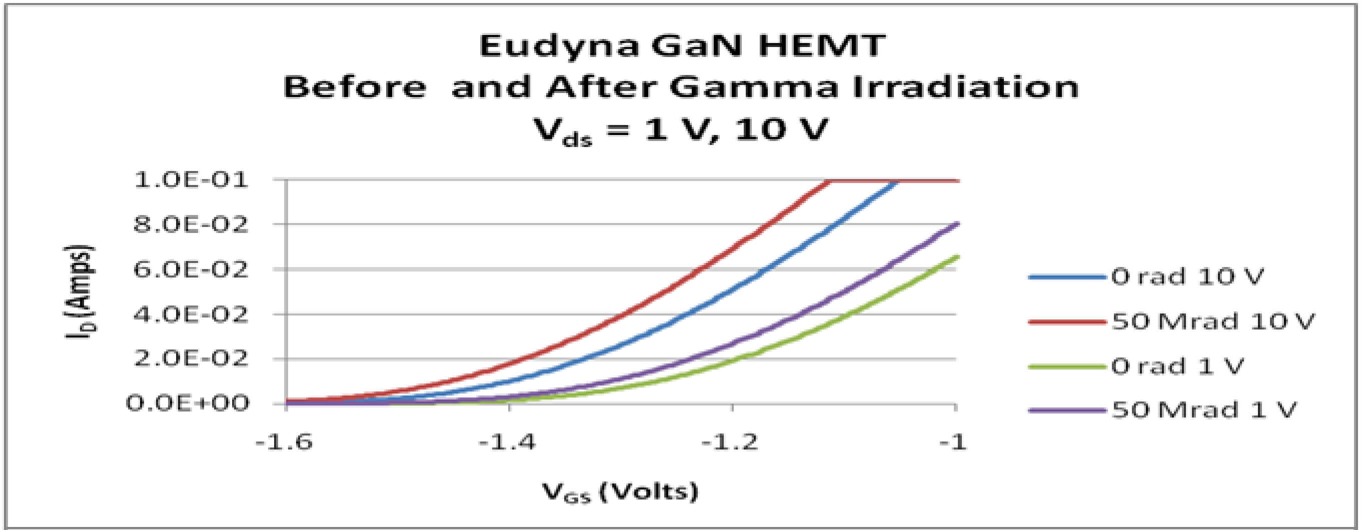
Max operating V & I Limit Power by duty cycle

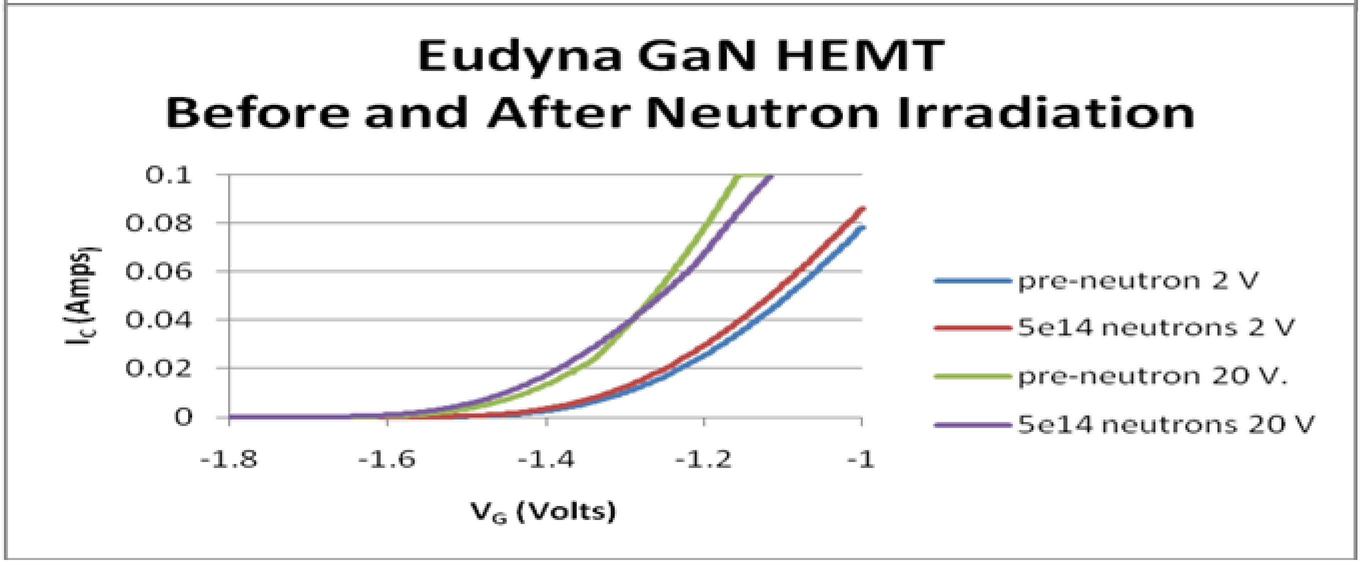


FET Setup for Proton Radiation Exposure



200 Mrads of Protons had no effect – switching 20 V 0.1 Amp
Parts still activated after 7 months





Our next IEEE TNS Paper shall summarize work to date

Proton Test

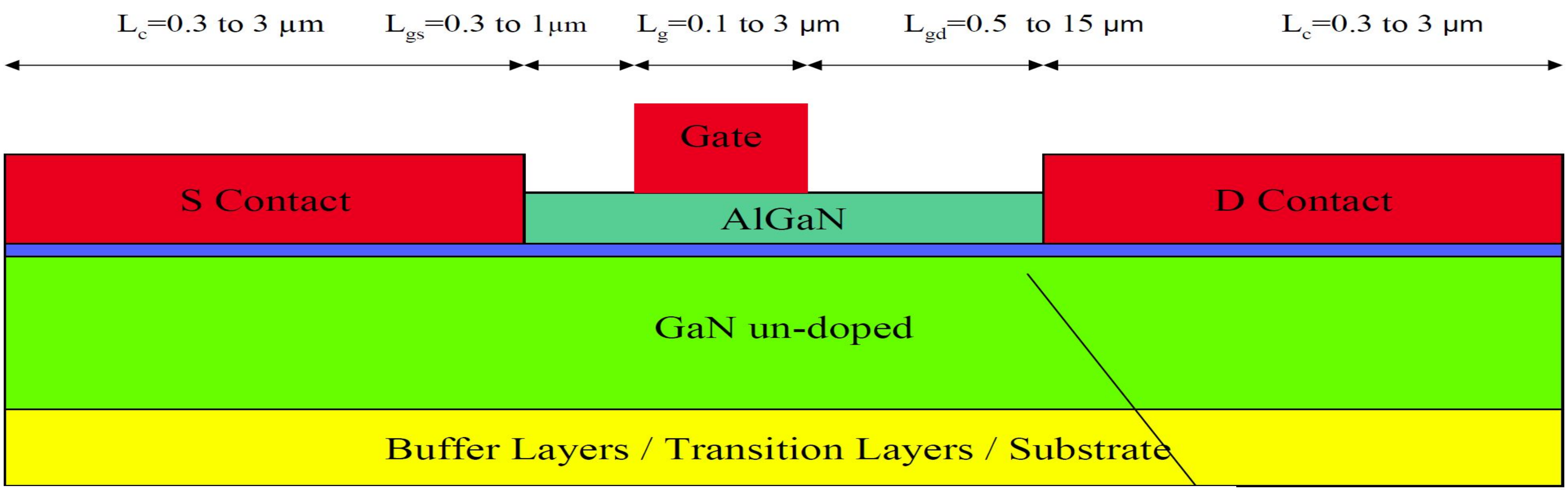
Proton Fluence =1 x 1015p/cm2 over a period of about 24 hours.

Biased = 65 volts switching @ 1MHz

Average current = 65 mA limited by Load resistor . No change in current.

GaN for Power Switching

- High frequency ~ 10 GHz
- Low Rds & low gate charge > High FOM: Figure of Merit
- High Thermal Conductivity & x10 higher Dielectric strength then Siliocn
- No Gate Dielectric !



Piezoelectric effects create 2 DEG electron sheet $n_s=10^{13}$ cm^{-2}

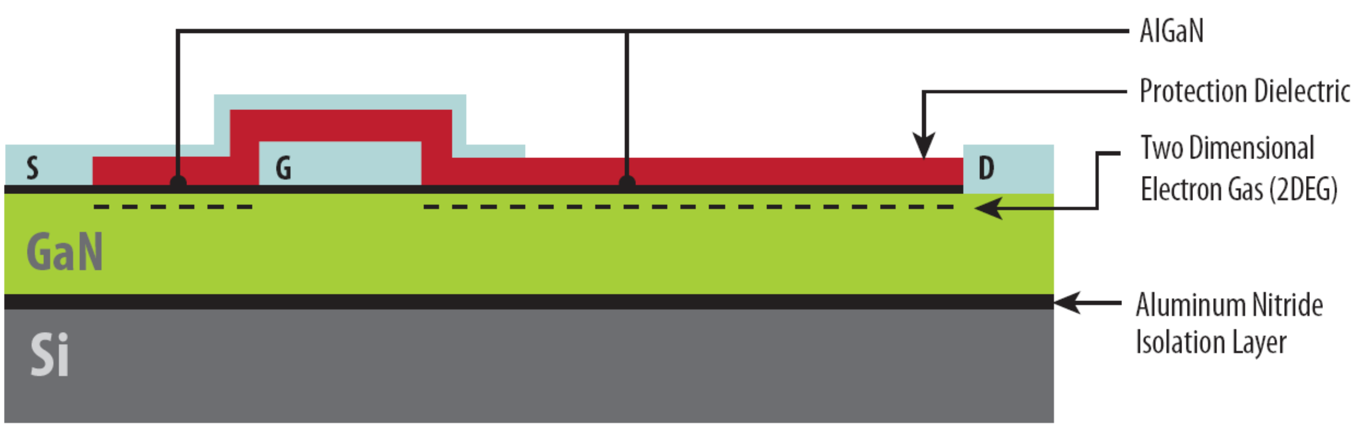


Figure 1: GaN on silicon devices have a very simple structure similar to a lateral DMOS device and can be built in a standard CMOS foundry

Gallium Nitride Power Devices Tests 2010

Power Devices

- Efficient Power Conversion Corp (EPC) GaN on Silicon
  5 Devices 40 - 200 Volts 3- 33 amps. *Sold by Digikey*
  600 V Device samples December 2010

- International Rectifier GaN on Silicon. Announced Feb 2010
  Not yet available for little people with no pockets

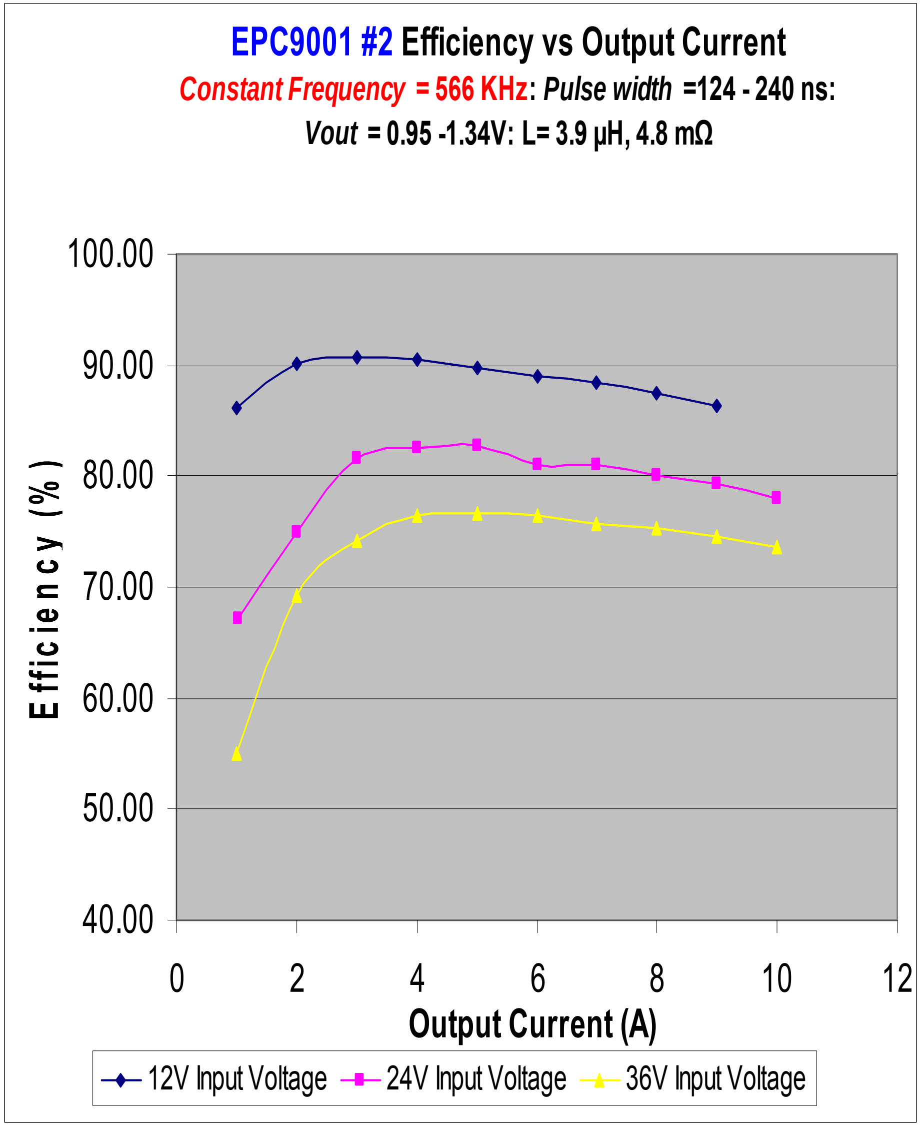
Irradiation
Organized by BNL & Yale

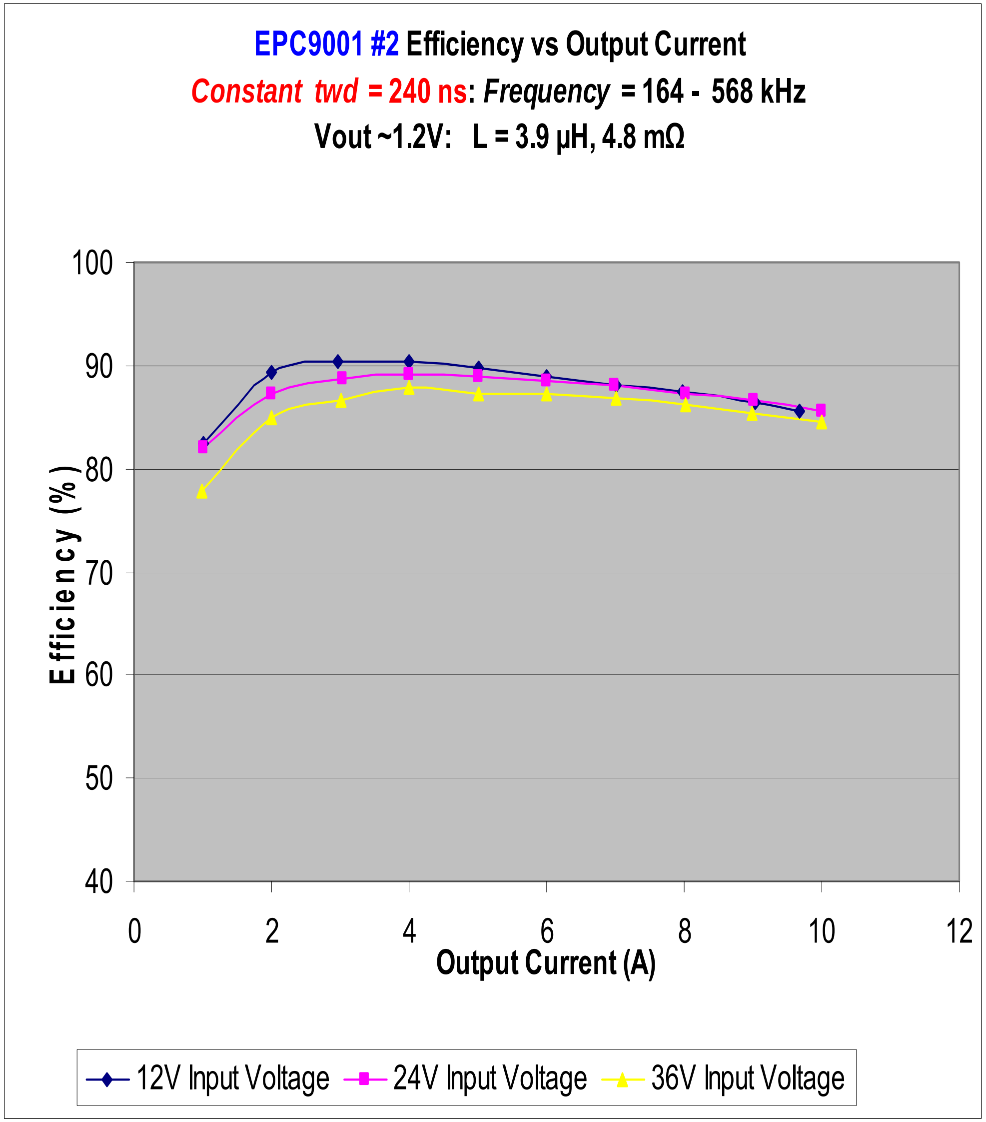
Gamma: @ BNL Aug – Sept 2010
Protons: @ Lansce August 2010
Neutrons: @ U of Mass Lowell ??

Irradiation
Organized by Sandia & Yale

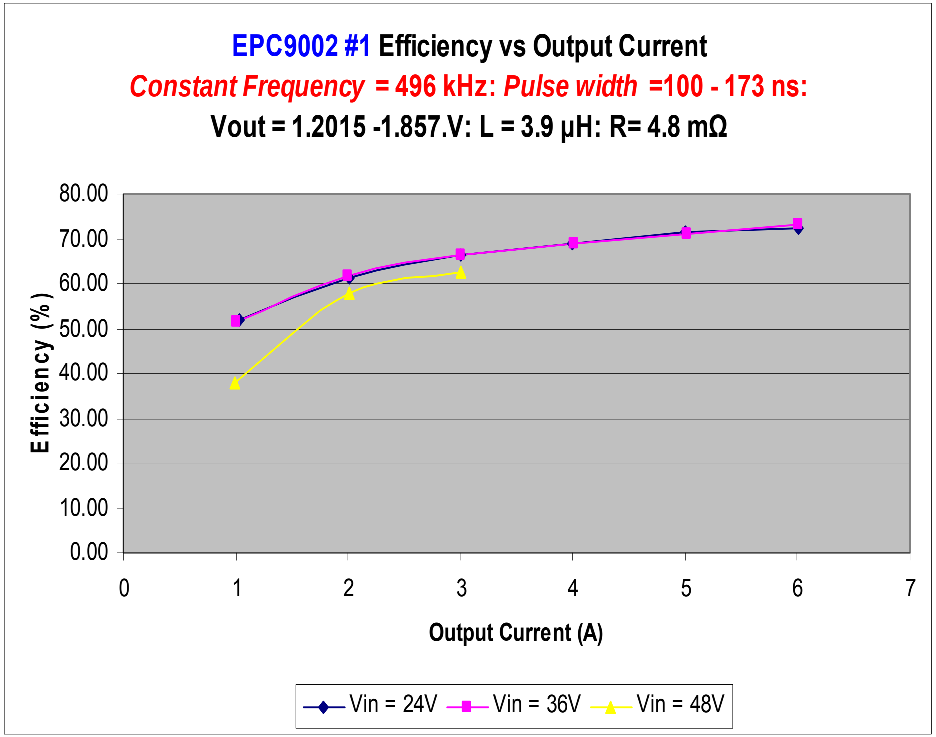
Gamma: @ Sandia $
Protons: @ TRIUMF September 2010 $
Heavy Ions: @ TAMU August 2010

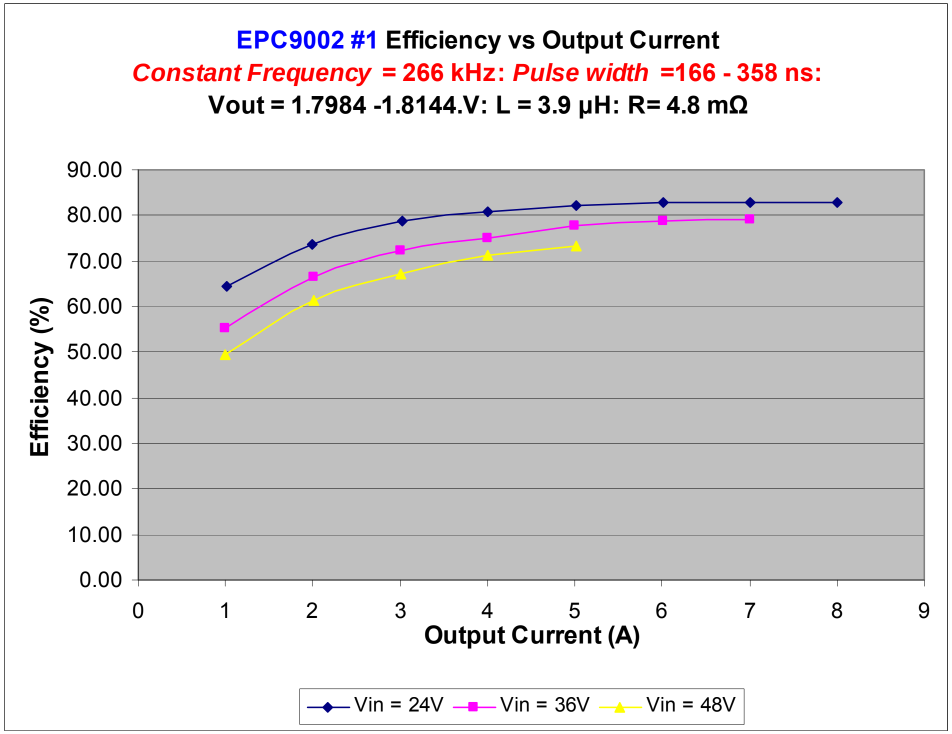
: epc 1015 – 40V: Efficiency with constant frequency and constant on pulse with inputs of 12, 24 & 36 Volts.



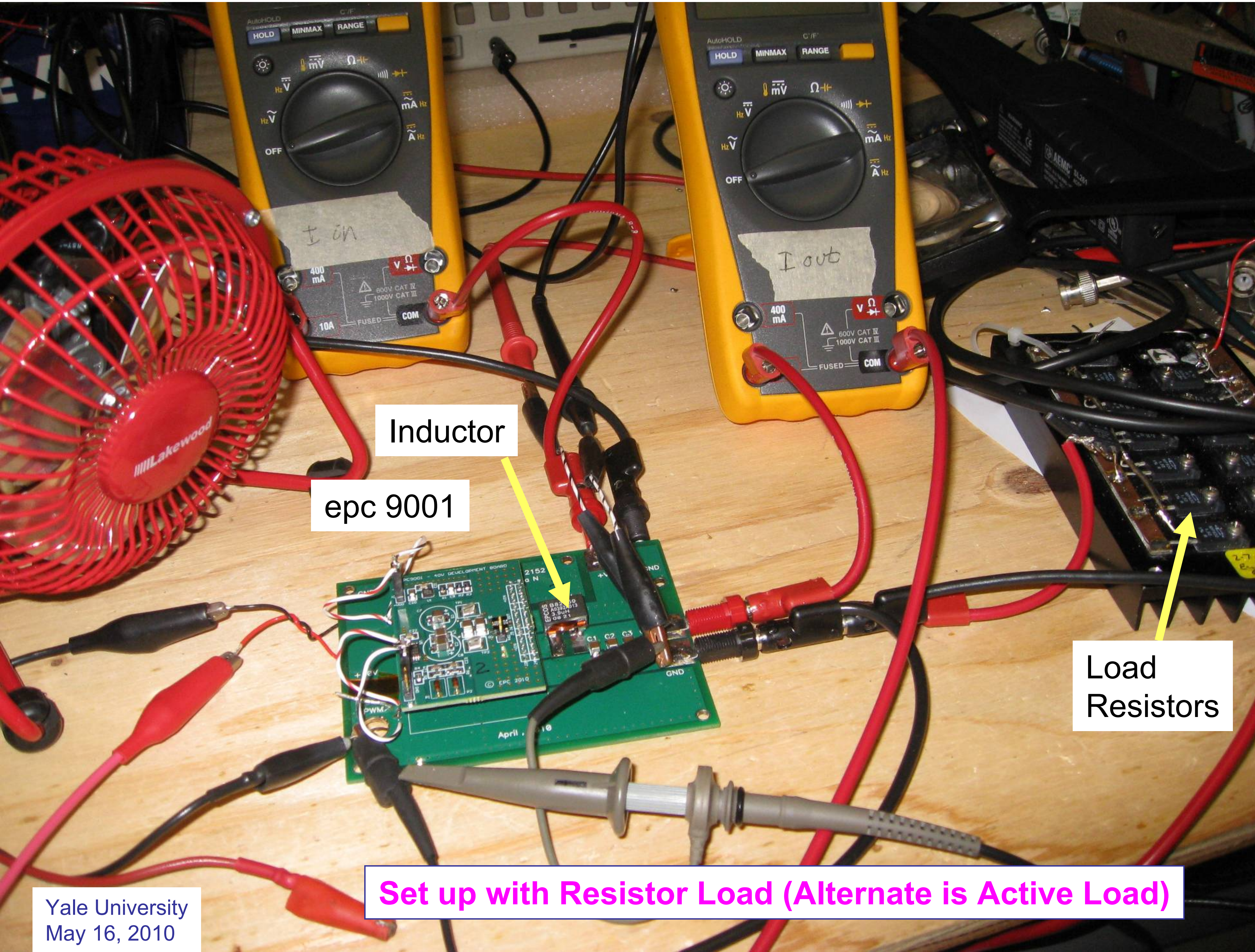


: epc 1001 – 100V: Efficiency with 2 constant frequencies. Inputs of 24, 36 & 48 Volts.

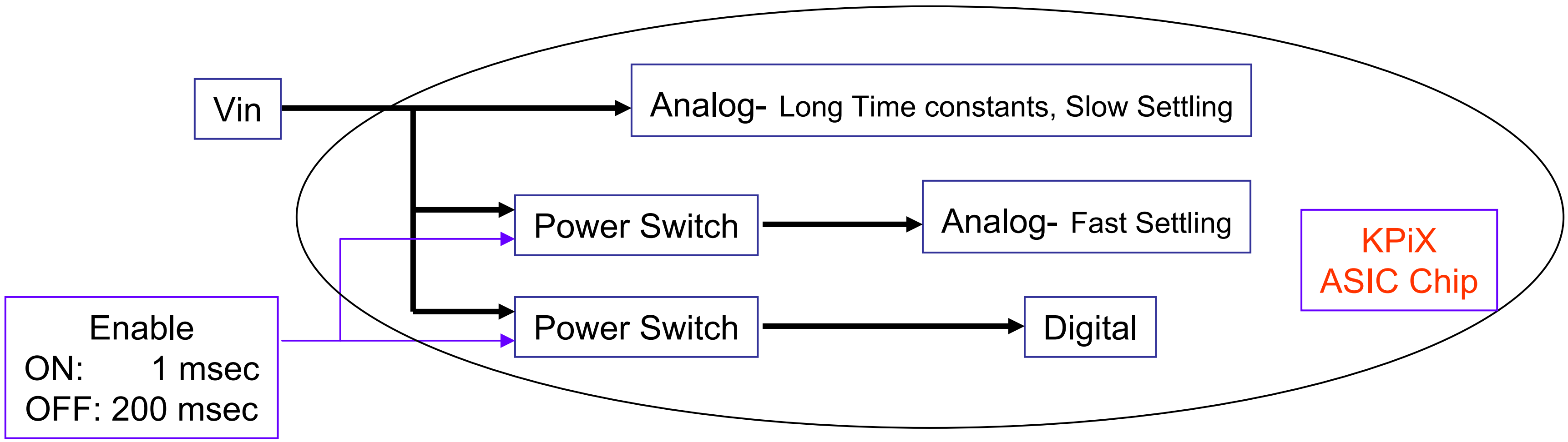


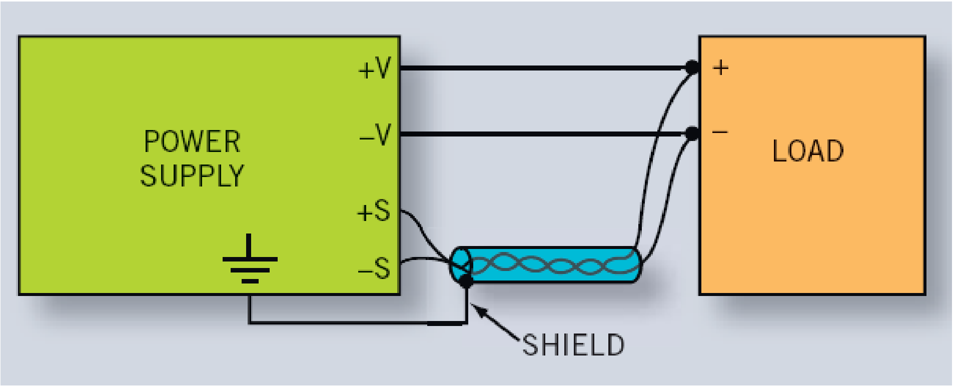


Need better GaN drivers preferably integrated on the wafer



Set up with Resistor Load (Alternate is Active Load)



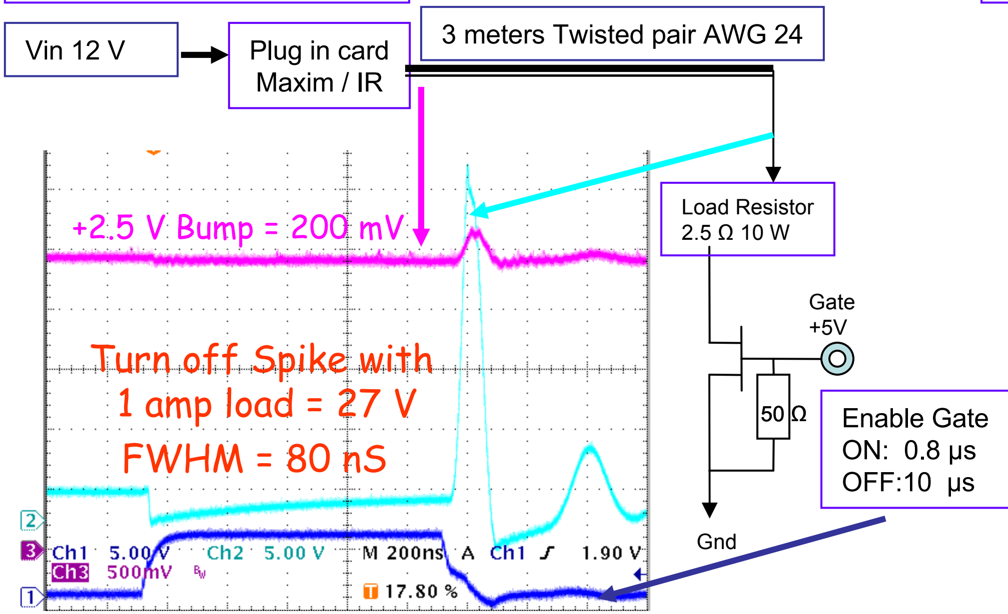


Powering ILC SiD Detector

SiD Powering Pulsing

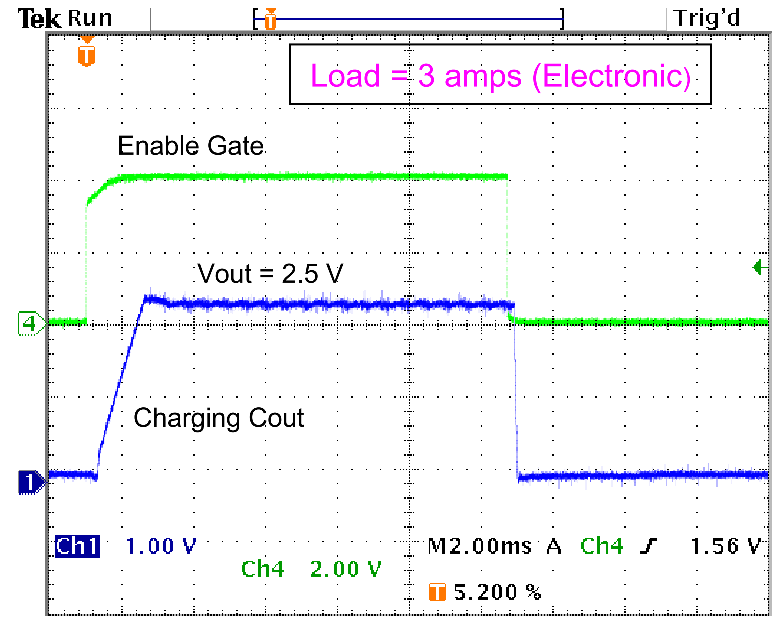
Pulsing Load

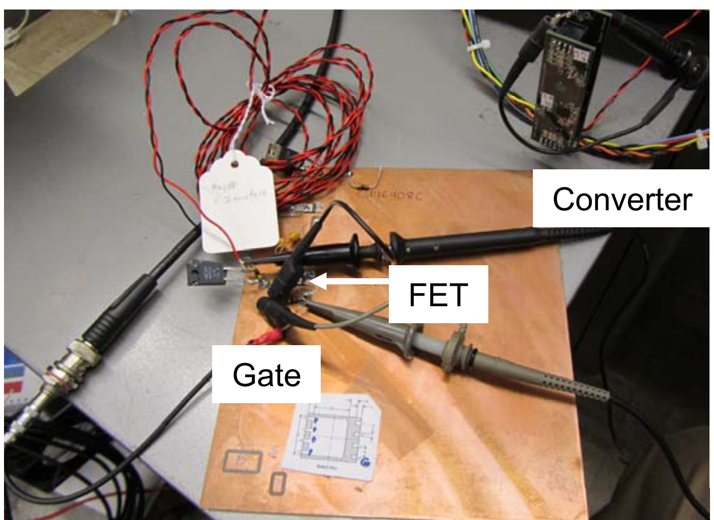
Air Coil DC-DC Converter

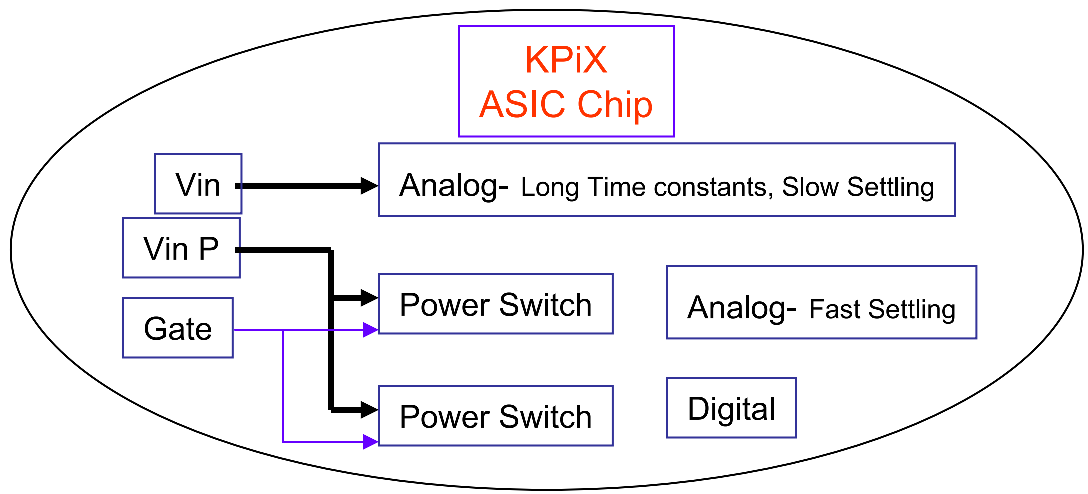


Pulsing Converter

Air Coil DC-DC Converter



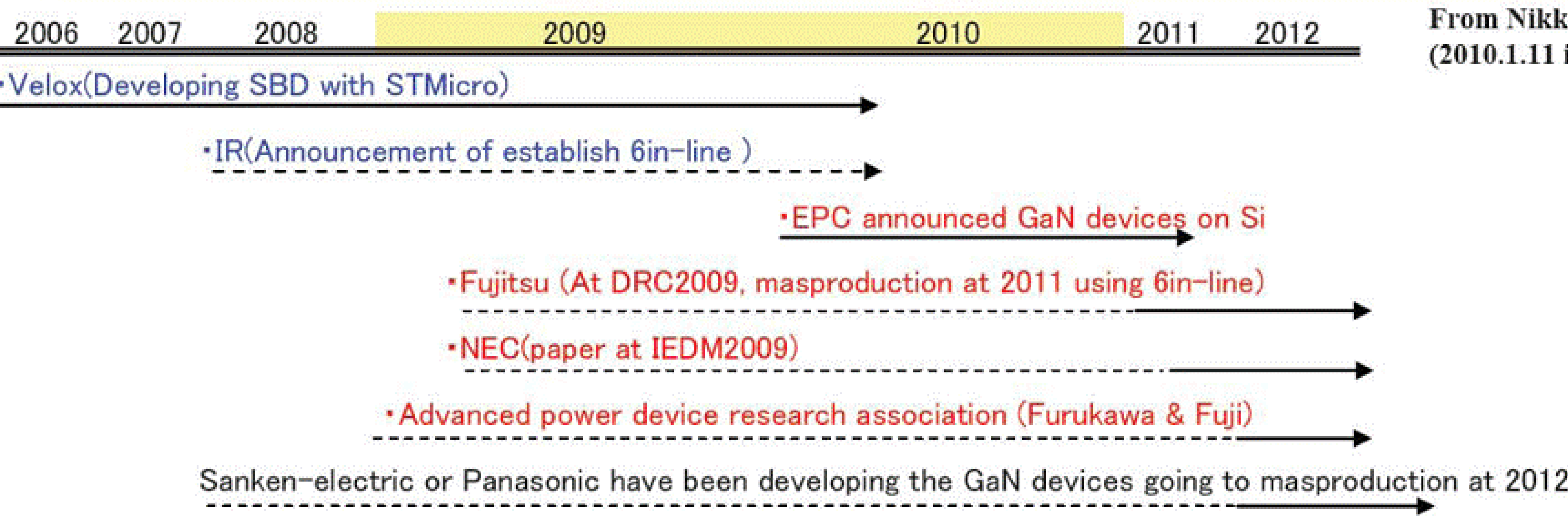




Status of GaN player

Prepared by Dr. Nariaki Ikeda
of Advanced Power Device Research Association
for Yale University

Company	Detail of Target or status
Fujitsu Laboratory	Mass-production level in 2011(fiscal)~2012 in the medium Vb over 600V using Si or SiC substrate (representative by Fujitsu Micro-elect.)
Furukawa and Fuji Electric	Commercial use at 2011(fiscal)
International Rectifiers	Commercial use from 2010 Beginning of product is lower Vb such several tens of voltage
NEC (Renesus)	Deliver Sample at 2011(fiscal)
Panasonic	Commercial use at 2011(fiscal)
Rohm	Deliver Sample at 2011(fiscal), also developing GaN native substrate
Sanken Electric	Trial manufacture of Vb over 800 V



From Nikkei electronics
(2010.1.11 in Japanese)

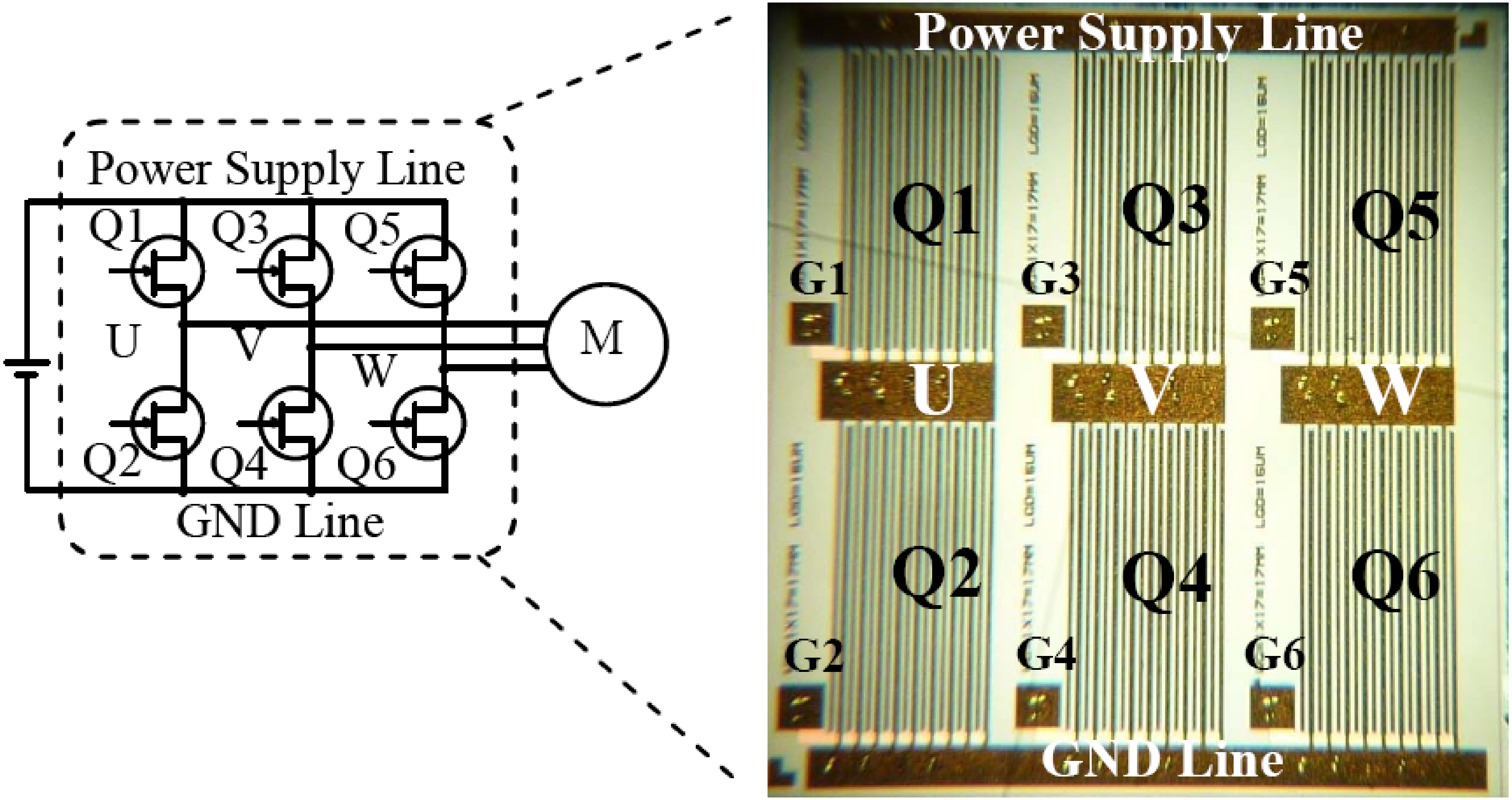


Fig.8 Chip photograph of fabricated GaN monolithic inverter IC in which 6 GITs are integrated.

Panasonic IEDM Motor Driver: Green Air Conditioners

2010年
6/9 WED
第1892号 毎週水曜日発行（祝祭日） 昭和58年7月21日第三種郵便物認可
THE SEMICONDUCTO
半導体産

Fujitsu

この人に聞く！ 半導体トップインタビュー

富士通セミコンダクター㈱
代表取締役社長
岡田 晴基 氏

President Fujitsu
H. Okada

300mmを月産2万枚に増強

――2009年度を振り返って。

岡田 09年8月、当社は①事業モデル（当社オリジナル型ファブライトの確立）、②費用構造（固定費を中心とした費用削減施策の実行）、③商品ポートフォリオ（アプリケーション・オリエンテッドの製品展開）の3大改革を発表した。また、それらをベースに09年度下期の営業利益黒字化を目標としていたが、実際には750億円以上の固定費削減（計画値は650億円）、下期についても約60億円の営業利益（計画値は約50億円）と、どちらも当初計画を上回る結果を達成することができた。これらの実現には"痛み"も伴ったが、社員全員が一体化という共通のテーマ・意識をもって取り組んだ結果であると思っている。

――10年度もさらなる固定費削減を計画しているが、具体的な施策は。生産ラインのさらなる統廃合の可能性は。

岡田 10年度については、昨年の計画からさらに100億円を上積みして、250億円の固定費削減を計画している。生産ラインの歩留まり改善だけでなく、各事業部内における業務のさらなる効率化など、全社的な取り組みで実現していく構えだ。

生産ラインのさらなる集約は考えていない。昨今の受注状況を見ると、デジタル家電や自動車に加え、産業用途も大きく伸びている。当社は09年度に前工程の6インチラインを1本、8インチラインを3本に集約した。300㎜を含め、ラインによって温度差はあるが、稼働率は80%台後半という状況であり、今後は生産効率をいかに上げて、さらなる需要の増大に対応していくかが課題となる。

――10年度の設備投資について。

岡田 10年度は160億円の設備投資を計画している。基盤分野（岩手工場、会津若松工場など）、先端分野（三重工場）に半々程度を見込む。

先述のとおり、今後は生産効率の向上がカギであり、必要な投資を随時行っていく。300㎜については、現在月産1万8000枚の処理能力だが、今年度は月産2万枚程度まで増強する。また、顧客のニーズを見極めながら、90nmから65nmプロセスへの切り替えを進めていく。

――4月1日から社名を「富士通セミコンダクター」に変更したが。

岡田 半導体製品・サービスを提供する企業であることがわかりやすい社名に変更し、グローバルな市場と顧客により一層認知していただくことを目指したものだ。また、今年度は反転攻勢の年と位置づけており、さらなる売り上げ拡大を狙う。

GaNパワーを12年に量産開始

社内的には、大きな組織変更を行った。当社では、成長の柱として、①モバイル/エコロジー、②自動車、③映像機器、④産業機器の4つの事業領域への注力を発表している。それらを大きく2つに分け、①と②をマイコンソリューション事業部、③と④をアドバンスト・プロダクト事業部が統括することで、より効率的な事業展開を図っていく。

10年度については、売上高3400億円を計画している。足もとの受注状況から上ぶれする可能性は非常に大きいが、現時点での上方修正などは考えていない。

――GaNパワーデバイスの新規事業計画について。

岡田 GaN関連については富士通研究所において開発が進められている。6月中にはサンプル出荷を開始し、12年上期には量産をスタートさせたい。量産工場については、会津若松工場の6インチラインが有力だが、市況によっては8インチラインへの移行も検討していく。

（聞き手・本紙編集部）

国内半導体大手12社の業績推移（単位：

	社名	08年度実績	09年度 4-6月	7-9月	10-12月
1	東芝	10,232 ▲2,799	2,257 ▲362	2,613 62	2,8[illegible]
2	ルネサス テクノロジ	7,027 ▲966	1,346 ▲224	1,489 ▲286	1,63[illegible] ▲3[illegible]
	NECエレクトロニクス	5,259 ▲664	964 ▲215	1,143 ▲154	1,13[illegible] ▲9[illegible]
3	ソニー	6,800 黒字	1,200	1,500	1,8[illegible]
4	エルピーダメモリ	3,310 ▲1,474	728 ▲423	959 8	1,51[illegible] 30[illegible]
5	パナソニック	3,929	782	885	[illegible]
6	ローム	2,979 105	724 ▲49	850 85	82[illegible] 10[illegible]
7	シャープ	3,406 ▲20	860 ▲20	898 21	[illegible]
8	富士通セミコンダクター	3,903 ▲600	686 ▲200	787	80[illegible]
9	日亜化学	1,279 432	275 30	384 86	[illegible]
10	三菱電機	1,250 ―	225 ―	255 ―	26[illegible]
11	三洋半導体	1,171 ▲203	220	271	[illegible]
	合計	49,545 ▲6,189	10,040 ▲1,263	12,214 ▲187	12,4[illegible] 4[illegible]

上段は売上高、下段は営業利益を示す。―は非公表
ロームの営業利益は全社ベース。シャープはLSI以外も一

（台南市）の12インチ工場と国内外の8インチ工場の設備能力増強、さらには台中における新たな12インチ工場の建屋建設に充てられる。投資額としては、ファブ12/14向けに10億5180万米ドル、8インチ工場向けに3億8500万米ドル、台中の新型12インチウエハー工場向けに2億1000万米ドル。台中の新工場にそれぞれ生産対応する計画だ。

この計画に合わせて同社は09年下期から積極的な設備投資を実施している。具体的には、同年投資額26億7100万米ドルのうち、下期だけで23億米ドルを投資している。なお、今年の設備投資額48億米ドルもさらに増額する可能性もあるという。

中国のチベット自治区ツガツェ市で2010年5月、発電容量10MWの太陽光発電施設が着工した。投資額は2億4900万人民元（約33億9000万円）で、12月初めに稼働を始める。第2期プロジェクトとして20MW規模の投資も計画している。

中国は世界の太陽電池の40%を生産しているにもかかわらず、太陽光発電システムの導入量はきわめて少ない。09年の導入量は180MWだったと中国電子材料産業協会はまとめている。

しかし、中国政府が09年に施行した太陽光発電の補助金制度「金太陽プロジェクト」により、合計640

Para Sonic

Ishigaro
President of Panasonic

GaNデバイス量産へ

パナソニック 10年度内有力

パナソニック㈱セミコンダクター社（京都府長岡京市神足焼町1、☎075―951―8151）は、GaNを用いたパワーデバイスの量産化に目処が立ったことを明らかにした。2010年度内を目標に量産化技術を確立し、早期の量産開始を目指す。

4月1日付で就任した同社の石黒永孝社長が、新デバイス戦略の一環として明らかにした。量産化に至るまでは歩留まり向上、コスト力の強化などの課題が残っているが、年度内には量産化技術を確立できる見通しが立っているという。搭載する機器については明らかにしていないが、低耐圧領域に強いGaNパワーデバイスの特性を活用できる白物家電などとみられる。

GaNパワーデバイスは高耐圧領域向けのSiCデバイスと比べて市場規模が大きく、同社では今後の展開に期待している。

石黒社長は従来パワーデバイスにあまり力を入れていなかったことにも触れ、「だからこそ逆に身軽にやれる」と今後パワーへの取り組みを強める意向を示した。将来的には現在パナソニック本社の研究開発部門で行っているSiC研究をセミコンダクター社へ移し、GaNデバイスとともに展開することも視野に入れているという。

4Gへのシームレスな移行を図る橋渡しの技術としてNTTドコモが提唱、国際標準化団体3GPPが規格を制定し、次期通信技術の世界標準規格と目されている▼昨年以来、国内のLTE関連ニュースには、ドコモと日本電気、パナソニック モバイルコミュニケーションズ、富士通の4社が通信プラットフォームを共同開発。また、ドコモは700MHzから2・5Gヘルツ帯で8周波数帯に対応した電力増幅器を開発、いずれも国内外の市場を見据えている。LTEにより通信規格という障壁が取り除かれつつある中、各国市場のニーズを満たす製品の迅速な開発により、国内携帯電話機や通信基地局用装置が世界市場に流通することを願う。

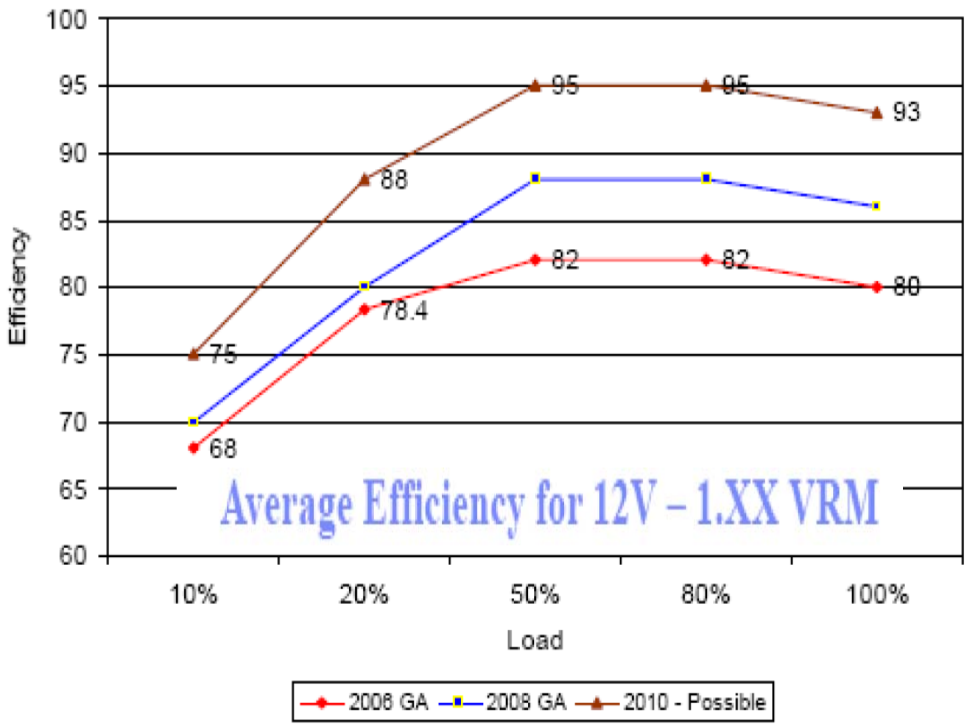
PSMA: Road Maps
Power Supply Manufacturer Association
Yale University is member

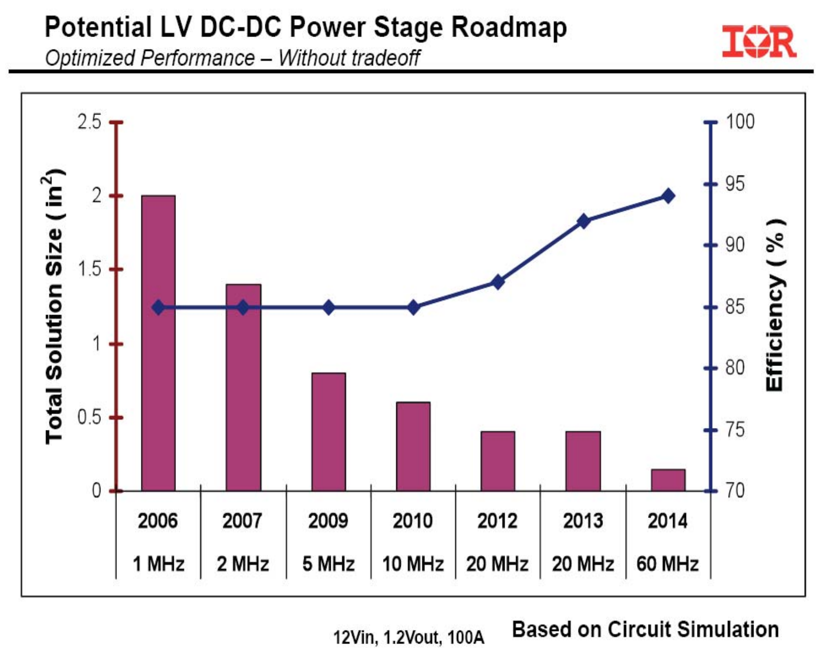
What is happening outside HEP ?

Server Power System Distribution from IBM

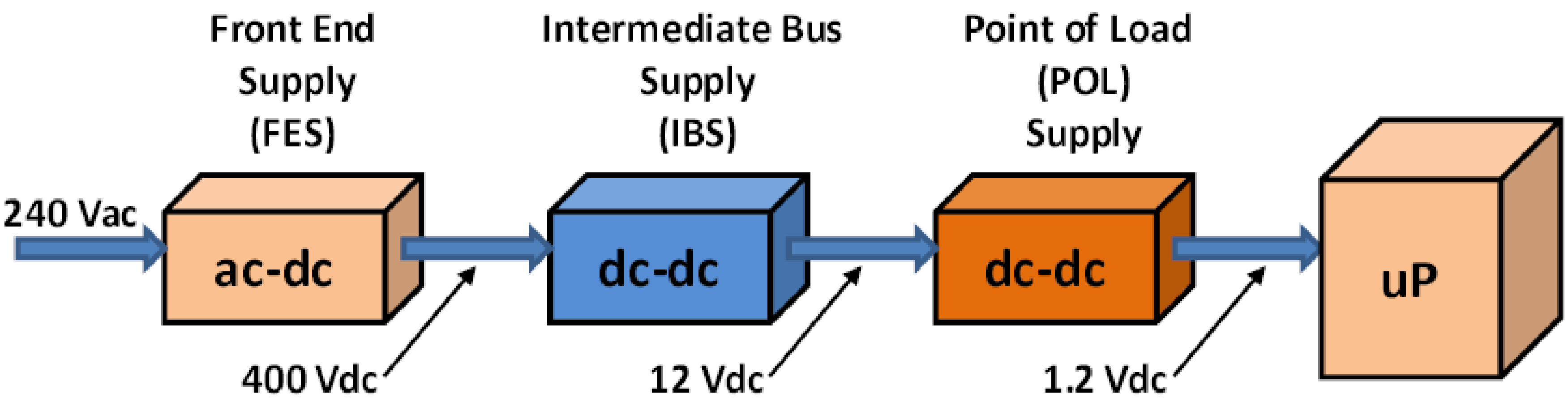
1. **AC Distribution - 208/230/115V**
   - Servers, Blade Servers, Workstations
2. **12V DC Distribution**
   - Blade Server Chassis, Low end and Midrange Servers, Workstations
3. **48V Distribution in a Rack**
   - High End Server Applications
4. **350V DC Distribution in a Server Rack or a Rectifier Cabinet**
   - Main Frame Servers

International Workshop on Power Supply On Chip
Sept 22nd - 24, 2008
October 13-15, 2010
Cork, Ireland





AC - DC Power Efficiency Challenge by IBM September 2007

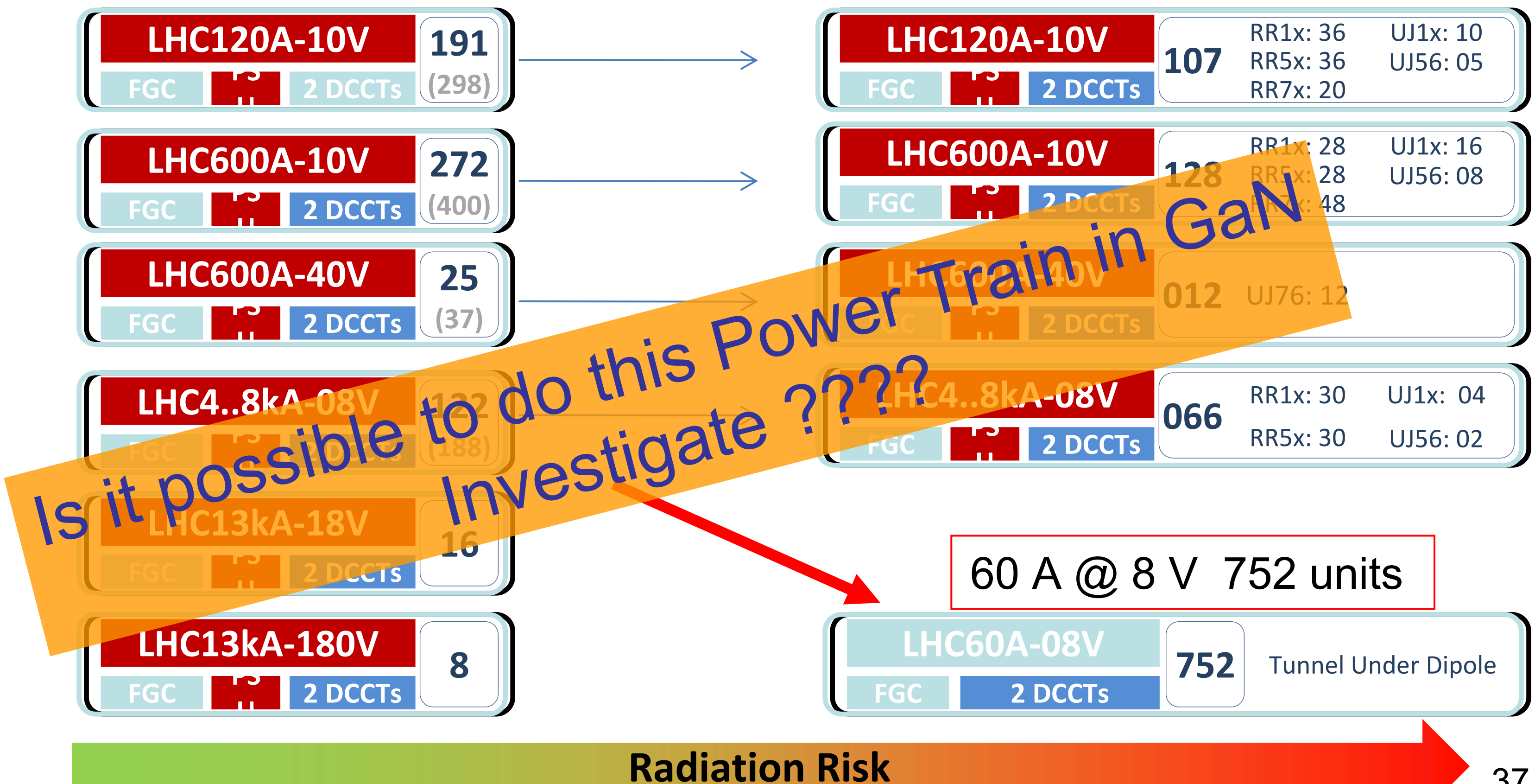


	FES	IBS	POL	Plug-to-Processor
Recent	93%	95%	88%	78%
Best Immediate	95%	98%	90%	84%
	IBM Challenge			***90%***
Needed	98%	98%	94%	***90%***

CONVERTERS INSTALLED

CERN – Chamonix 2010 Report

- **LHC CONVERTERS VS RADIATION *[2010]***
  - Rad Tolerant Design *or* standard Design with low Rad sensitivity (safe components)
  - Standard Design *and* Rad sensitivity unknown (too many components, sub-assemblies...)



Review of the radiation tolerance of LHC power converters

Date: April 13 -14 2010

Reviewers: Bill Bartholet, Boeing (Email: bill.bartholet@boeing.com). Jorgen Christiansen, CERN/PH-ESE (Email: Jorgen.christiansen@cern.ch). Federico Faccio, CERN/PH-ESE (Email: Federico.Faccio@cern.ch). Rémi Gaillard, Consultant (Email: gaillardremi@wanadoo.fr). Bob Lambiase, BNL (Email: lambiase@bnl.gov). Rick Tesarek, Fermilab (Email: tesarek@fnal.gov). Kay Wittenburg, DESY (Email: kay.wittenburg@desy.de).
Prevented to be present in review meeting: Claudio Rivetta, SLAC (Email: rivetta@slac.standford.edu).

Source of Material: http://indico.cern.ch/internalPage.py?pageId=0&confId=85477

Executive summary: This review of the radiation tolerance of the power converters for the LHC accelerator concludes that the current power converters at their current locations introduces a significant risk for the reliable running of the LHC at high luminosities. At nominal LHC luminosity it can be estimated that radiation induced transient and destructive failures in the power converters might seriously limit the beam availability for physics.

For the initial 1st physics run (2010 -2011), at low luminosity, the currently implemented shielding improvements is estimated to allow the current power converters to have sufficient reliability. There is in practice no other alternative, as no major improvements can be introduced during the running period.

For the planned 2nd physics run (2013-2014), at increased luminosity and increased energy, radiation induced failures can become a limiting factor for the running of the accelerator (directly dependent on luminosity). Because of the limited time available only minor incremental improvements can in practice be implemented to improve this (relocation, improved shielding and minor power converter modifications). It is proposed to perform a paper vulnerability analysis of the current power converters as soon as possible. Part-level radiation tests of identified high risk components can then be made to determine where such improvements can be implemented to reduce the global risk.

For the long term running at full nominal luminosity the current power converters can be expected to become a serious limitation for the effective running of the accelerator. They should therefore be replaced by new radiation tolerant converters or the current converters must be relocated to areas without radiation. The design and production of new radiation tolerant power supplies will require a significant time and should therefore be started as early as possible.

Conclusions

- The power distribution needs of HEP detectors require new solutions/technologies to meet power and environmental requirements.
- DC/DC (Buck) Converters are potential solutions for these needs.
- The environment requires that these converters operate in high radiation environments and high magnetic fields at high switching frequencies in a small size/mass package.
- Target technologies for the switches are radiation hard GaN and 0.25 μm LDMOS. High frequency controllers driving small sized nonmagnetic/air core inductors are also required.
- Many of these components have been tested and now need integration to produce a working prototype. This is the next step in our R&D program.

What can be achieved by this Development ?

- Current Reduction from Power Supply by DC-DC near Load
  Losses > Current^2 x Resistance

- Silicon ÷10 Current Reduction 5 Oodle > 0.5 Oodle
  Power Loss reduced by 100

- GaN ÷ 50 Current Reduction 5 Oodle > 0.1 Oodle
  Power Loss reduced by 2500
  Power Converters for Beam Line usage ??

Thermal Challenge

A grain of Basmati Rice
4 watts

GaN FETs
40 V 33 A 4mΩ

FET Solder side


Working on Power Supply
Is not Glamorous
Top of the World is Cool but lonely !
Let us keep it cool with highly efficient PS
Swimming is Great at the North Pole
More Details: http://shaktipower.sites.yale.edu/